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WATER RESOURCES ACTIVITIES IN THE UNITED STATES. POLLUTION ABATEMENT

Select Committee on National Water Resources, U. S. Senate

January 1960

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86th Congress
2d Session

COMMITTEE PRINT NO. 9

WATER RESOURCES ACTIVITIES
IN THE
UNITED STATES

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POLLUTION ABATEMENT

SELECT COMMITTEE ON NATIONAL WATER RESOURCES
UNITED STATES SENATE

PURSUANT TO

S. Res. 48

EIGHTY-SIXTH CONGRESS

JANUARY 1960

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This letter has been reproduced to correct errors contained in the report of the Public Health Service to the Senate Select Committee on National Water Resources which appear in Committee Print No. 9, "Pollution Abatement."

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE,
PUBLIC HEALTH SERVICE,
Washington, D.C., March 31, 1960.

Hon. ROBERT S. KERR,
Chairman, Select Committee on National Water Resources,
U.S. Senate, Washington, D.C.

DEAR SENATOR KERR: We believe that it would be desirable to modify the wording of two of the items contained in the appendix of part II of our report to your Senate Select Committee on Water Resources. This part of our report was published by your committee as Committee Print No. 9, entitled "Pollution Abatement." As now written, the items entitled "Delaware" and "Philadelphia, Pa.; Ground Water Pollution," on pages 27 and 28 of that document impart an erroneous understanding of the illustrative situations which they are intended to describe. To correct this situation, we are suggesting that you include in part III, of our report, which is about to be distributed as Committee Print No. 24, an errata sheet setting forth the following revised wording for the items in Committee Print No. 9 which are in question.

Page 27, column 2, bottom of page

Title should read "Delaware River at Wilmington, Del." First sentence should read "At Wilmington, Del., 'pollution, as well as salt water intrusion, has made the use of the Delaware River impractical as a source of municipal water supply.' "

Page 28, first column, middle of page

Change title from "Philadelphia, Pa." to read "Southwestern New Jersey."

Change first sentence to read "In the Camden area, the polluted waters of the Delaware River have been infiltrating into the major ground water reservoir serving the area during period of heavy pumpage."

Eighth line: Change "Paritan" to read "Raritan."

Change sixth sentence in paragraph to read: "The possibility exists in the southwestern New Jersey area also for the intrusion of salt water from the ocean via Delaware Bay and River." Change seventh sentence to read: "Channel deepening in the Delaware River has increased the extent of the salt water excursion, and in addition, has uncovered the deeper aquifers lying under the river bottom."

There are also a few typographical errors in Committee Print No. 9 which should be pointed out.

Page 10, under the heading of "Salts"

The figure "15,000 tons" should read "25,000 tons."

Also, the last clause in the last sentence of this paragraph should read ", and other cities were handicapped in tapping this otherwise acceptable lake as a badly needed auxiliary source of water."

Page 37, first column, third line

Change 50 percent to 33 percent.

Page 37, second column, end of twelfth line under title "San Joaquin Basin, California"

Change "bay area" to read "basin".

Page 38, first column, line 4

Change "full streamflow" to read "low streamflow".

Page 38, San Francisco Bay, last line

Eliminate "of the waters."

We regret the necessity of these corrections but believe the report will be of greater value if they are called to the attention of the readers.

Sincerely yours,

L. E. BURNEY, *Surgeon General.*

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STATEMENT BY THE CHAIRMAN

JANUARY 12, 1960.

To the Members of the Select Committee on National Water Resources:

At the beginning of our studies under the provisions of Senate Resolution 48, it became evident that problems relating to the maintenance of the quality of water are as critical as the problem of supply. All of us have been concerned with the growing inability of many of our smaller communities to cope with the serious pollution problems brought about by the rapid growth in urban population and increased number of industrial plants. The Congress has previously taken note of the need for action in this field and in 1956 enacted Public Law 660 of the 84th Congress which set up a program of Federal assistance in meeting these needs. There has been a great deal of progress under this authorization, but the needs likewise have increased manyfold, and we now have legislation pending to expand the program of Federal assistance.

Recognizing pollution abatement as a growing problem which must be dealt with if our needs for an adequate supply of water of adequate quality for all segments of our economy are to be met in future years, I asked the Secretary of the Department of Health, Education, and Welfare to prepare a report for the committee covering the present and future extent of water pollution hazards brought about by industrial and municipal sewage and other waste materials disposed of in water. I suggested that the report cover recent trends in the production and treatment of wastes, the relationship of sediment loads in our rivers to other pollution, and the Department's views as to requirements and recommendations for pollution control measures needed between now and 1980. The report of the Department of Health, Education, and Welfare on this subject has been prepared as the second part of the Department's three-part study for the committee covering municipal water supply, pollution abatement, and the need for better water quality management if our needs are to be met.

The Department's report clearly points out the magnitude of the problem which confronts the American people in their search for clean water. In addition to the normal problems of disposal of sewage and ordinary industrial wastes we are now confronted with many new types of wastes resulting from our technological advances. Eight different classifications of pollution are discussed. The report points out that many of these new pollutants such as synthetic organic chemicals, radioactive substances, and newly identified viruses and disease-producing micro-organisms which may enter water supply sources are very persistent and that little is known of their behavior.

I believe this report will be of great interest to the members of our committee, to other Members of the Senate, and to all others interested in the maintenance of clean uncontaminated surface and ground waters. Accordingly, I am having it printed as one of our series of committee prints dealing with all aspects of water resources activities.

ROB'T S. KERR, *Chairman.*

COMMUNICATIONS

JUNE 24, 1959.

Hon. ARTHUR S. FLEMMING,
Secretary of Health, Education, and Welfare,
Department of Health, Education, and Welfare, Washington, D.C.
(Attention Leroy E. Burney, Surgeon General, Public Health Service).

MY DEAR MR. SECRETARY: Reference is made to my letter of June 15, 1959, concerning the work of the Select Committee on National Water Resources. Among the other facets of the committee's work on which an early start must be made is preparation of materials relating to municipal water use and to the use of water for pollution abatement. Among the Federal agencies working in the water field the committee believes that the Public Health Service has unique qualifications for dealing with these matters. Accordingly, it is requested that reports on these two subjects be prepared for this committee by the Public Health Service.

The first of these reports should give us information relating to water use and related matters along the following lines:

1. Per capita water use for domestic, commercial (to include industrial service normally supplied through municipal water systems), and municipal public purposes. We would like to have information on 1959 or another recent year, some information on past trends, and projections on use in 1970, 1980, and 2000. We would like to have this information broken down by State with specific consideration given to major metropolitan areas, in particular Albuquerque, Boston, Chicago, Dallas-Fort Worth, Houston, Kansas City, Los Angeles, New York, Philadelphia, Phoenix, San Francisco, and Washington, as well as any other municipality having unusual problems.

2. Discussion of expected changes in rate of water use giving components of the changes.

3. Relation of cost to use of water and any other information which will throw light on supply-demand relationships for water.

4. Description of major problems in municipal water supply which may be anticipated from projected water use trends covering particularly municipalities or metropolitan areas having unusual problems.

5. Discussion of most efficient municipal water service and use at minimum levels of water consumption.

6. Any other matters in the field of municipal water use in relation to other uses of water which the Public Health Service believes should be brought to the attention of the committee.

The second report should give us information on present pollution hazards and projections of future pollution hazards, generally as follows:

1. Estimated extent of water pollution from industrial water use by type, source, and stream, at present and in 1970 and 1980, with an appraisal of recent effects on water quality by major industrial classification and type of effects. Trends should be discussed and specific examples should be cited. For this category we are concerned primarily with pollution of an inorganic character.

2. Extent of stream and underground water pollution by organic material from municipal sewage and other sources at present and in 1970 and 1980, considering population increases, sewage treatment trends, and other pertinent factors.

3. An estimate of the present extent of avoidable sediment load originating on land with a disturbed vegetative cover, by stream, with comments on the relationship of this type of pollution to other pollution hazards.

4. An appraisal of the extent to which streams should function as waste carriers by 1980.

5. Estimated requirements for water pollution control measures to 1970 and 1980, with recommended measures.

6. Any other matters in this field which the Public Health Service believes should be brought to the attention of the committee.

We would like this information to be made available in the form of two reports of not more than 10,000 words each, with whatever tables, charts, appendixes, and graphic illustrations as may be considered necessary. It would be most helpful if this information could be furnished the committee by October 1, 1959.

The committee staff will be happy to discuss any problems that may arise in the preparation of this material with representatives of the Public Health Service.

Sincerely yours,

ROB'T S. KERR, *Chairman.*

JANUARY 7, 1960.

Mr. THEODORE SCHAD,
Senate Select Committee on National Water Resources,
New Senate Office Building, Washington, D.C.

DEAR MR. SCHAD: Transmitted herewith are three copies of part II of our report to the Senate Select Committee on Water Resources, on "Future Municipal Water Supply and Water Pollution Control Requirements." This part is entitled "Present and Future Pollution Loads and Problems." Part I has already been sent to you. Part III will follow in a few days.

As pointed out in our letter transmitting part I, it may be found desirable to make a few changes in this part of the report to conform it to part III as it is completed. Also, the whole final report will probably be transmitted to Senator Kerr officially by Surgeon General Burney, but because of the urgency of the committee's requirements, the separate parts are being made available to you in this fashion, as they are completed, in order to expedite your committee's work.

Sincerely yours,

KEITH S. KRAUSE,
Chief, Technical Services Branch,
Division of Water Supply and Pollution Control.

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POLLUTION ABATEMENT

Part II of Studies by the Public Health Service of the Department of Health, Education, and Welfare

PRESENT AND FUTURE WATER POLLUTION LOADS AND PROBLEMS

STATEMENT OF THE PROBLEM

The national water pollution problem is a complex one, involving many facets. Water is withdrawn for use over and over again for many purposes as it flows to the sea. Most of this water is taken for granted and is used freely for all purposes, including the disposal of waste materials. Because of this indiscriminate usage, water is becoming badly polluted. The expanding need for water, therefore, emphasizes the necessity of preserving its quality, as demand rapidly approaches a final limit of supply.

Several factors have contributed to this critical situation. In addition to the tremendous population increases occurring during the past two decades, with their attendant waste disposal problems, our postwar technology has introduced into our environment many new types of industrial and other wastes, such as synthetic organic chemicals and radioactive materials. Many viruses and other disease-producing organisms are equally involved in our water pollution problems.

This section of our report discusses these various pollution factors in detail, and presents projections of pollution loadings which provide a basis for future action. Information and estimates of cost on municipal treatment facilities are also included.

CLASSIFICATION OF WATER POLLUTANTS

Water pollution may be defined as the adding to water of any substance, or the changing of water's physical characteristics in any way which interferes with its use for any legitimate purpose. Thus, the addition of toxic chemicals in harmful concentrations or the presence of compounds that aggravate taste and odor problems in potable water supplies must be considered pollution. An increase in nutritive substances resulting in excessive troublesome aquatic growth is pollution. Increased water temperature in streams is detrimental to aquatic environment and to the reuse of water by industry for cooling purposes. Erosion of soil from land areas and resuspension from the stream bottom may result in or add to a polluted stream condition. The introduction of pathogenic organisms and a host of noxious substances by sewage is pollution.

Water polluting substances may be classified according to eight general categories: (1) Sewage and other oxygen demanding wastes, (2) infectious agents, (3) plant nutrients, (4) organic chemical exotics, (5) other mineral and chemical substances, (6) sediments, (7) radioactive substances, and (8) heat. Water polluting substances are discussed under these various category headings in the following sections.

1. Sewage and other oxygen demanding wastes

This category covers the traditional putrescible organic substances which come mainly from domestic sewage and from such industries as food processing plants. These wastes are so named because, under normal conditions, they are reduced to stable compounds through the action of so-called aerobic bacteria, which require oxygen in their life processes. This oxygen is taken from the dissolved oxygen normally found in water under natural conditions, and this type of pollution is measured in terms of the amount of oxygen required. The oxygen requirement is called the biochemical oxygen demand, usually abbreviated to BOD.

When the oxygen demands of organic pollution reduce the dissolved oxygen in a stream below about four or five parts in a million parts of water, only rough fish life can normally exist. When the oxygen in the stream is reduced to zero by these demands, a different type of bacterial action occurs, as nonoxygen demanding, or anaerobic,

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bacteria take over the job of reducing the organic pollutants to inert materials. This latter situation produces what is called a septic condition, and the receiving waters take on the familiar dark, evil appearing, foul smelling condition which is characteristic of grossly polluted water.

Population growth and redistribution as a basis for estimating municipal sewage loads.— Just as the need for water is related to population, so is the production of sewage and associated wastes. Prior to World War II, it was predicted that the population of the United States would reach a plateau of about 170 million by 1975 and remain more or less static thereafter. Instead, we are experiencing an explosive population growth and in 1957 had already passed the 170 million mark, 18 years ahead of schedule. Population projection prepared by Resources for the Future suggest that population may reach 244 million by 1980, and 329 million by the year 2000, at the medium rate of growth.

Most of this population increase will be in metropolitan areas. It is conservatively estimated that the larger metropolitan areas will contain 70 percent of the total population by 1980 and 80 percent by year 2000, when 95 percent of the total population are expected to reside in urban places. The magnitude of the problem of disposing of municipal sewage will grow in direct proportion to this increase in urban populations.

The population projections upon which the following estimates of municipal sewage loadings are based are contained in Committee Print No. 7. These data are shown by States, water resource regions, and selected metropolitan areas.

Projections of municipal sewage loadings.— Municipal sewage includes those wastes from domestic, commercial, public, and industrial establishments discharging through municipal sewer systems. Perhaps 80 percent (by number, rather than by volume or value of products) of the industrial establishments in the United States are connected to such systems, and it is estimated that approximately one-third of the organic wastes treated by municipalities are industrial in origin.

Analysis of average municipal sewage indicates that 0.17 pound of oxygen is needed to stabilize the daily sewage and related wastes of one person. By using this figure to measure the demand for oxygen by industrial wastes, these wastes can also be expressed in terms of "population equivalents." This unit is therefore useful in measuring or estimating the totals of present and future oxygen-demanding pollution loads from both municipal and industrial sources. It does not apply to other pollution materials, however, such as common salt, cyanide, detergents, synthetic organic chemicals, and other materials that are not easily broken down by chemical and biological action. The unit is useful, nevertheless, in expressing pollution loads placed on water resources because many stream quality criteria are based upon the concentration of dissolved oxygen remaining in water after receiving a sewage discharge.

The present and projected future population equivalents of municipal sewage discharged to our surface waters are presented in tables 1, 2,

TABLE 1.—*Projected municipal sewage loads in continental United States, by States*

[In terms of equivalent population]

[Millions of people]

	1954	1980	2000
U. S. total	75.3	91.9	98.5
Alabama	1.0	1.2	1.3
Arizona	.4	1.0	1.2
Arkansas	.5	.4	.3
California	7.3	11.9	13.3
Colorado	.7	1.1	1.1
Connecticut	1.2	1.5	1.5
Delaware	.2	.3	.4
District of Columbia	.6	.5	.4
Florida	1.7	3.7	4.3
Georgia	1.2	1.6	1.7
Idaho	.2	.3	.3
Illinois	5.0	5.6	5.6
Indiana	1.8	2.2	2.4
Iowa	.9	.9	.9
Kansas	.8	.9	1.0
Kentucky	.8	.8	.9
Louisiana	1.2	1.6	1.8
Maine	.3	.4	.4
Maryland	1.2	2.0	2.2
Massachusetts	2.8	2.6	2.4
Michigan	3.6	4.8	5.2
Minnesota	1.2	1.4	1.4
Mississippi	.4	.5	.5
Missouri	1.9	1.3	1.3
Montana	.2	.3	.3
Nebraska	.5	.5	.5
Nevada	.1	.2	.3
New Hampshire	.2	.2	.2
New Jersey	3.2	3.9	4.0
New Mexico	.3	.5	.6
New York	9.5	9.1	8.8
North Carolina	1.1	1.3	1.4
North Dakota	.1	.1	.1
Ohio	4.4	5.1	5.3
Oklahoma	.8	.9	.8
Oregon	.6	.8	.9
Pennsylvania	5.4	5.0	4.9
Rhode Island	.4	.5	.5
South Carolina	.6	.9	1.0
South Dakota	.2	.2	.2
Tennessee	1.1	1.2	1.3
Texas	4.1	6.1	6.5
Utah	.4	.6	.6
Vermont	.1	.1	.1
Virginia	1.2	1.9	2.1
Washington	1.2	1.6	1.8
West Virginia	.5	.4	.4
Wisconsin	1.5	1.7	1.8
Wyoming	.1	.1	.2

NOTE.—Sums of the figures for the individual States will not add to the totals for the United States because of the different bases used in computing these 2 sets of figures.

TABLE 2.—*Projected municipal sewage loads in continental United States, by water resources region*

[In terms of equivalent population]

[Millions of people]

Basin	1954	1980		2000	
		Medium	High	Medium	High
New England	4.8	4.9	4.9	3.3	4.7
Delaware and Hudson	12.3	12.7	14.7	11.2	14.8
Chesapeake Bay	4.2	5.2	6.3	5.3	7.3
Eastern Great Lakes	6.1	6.8	7.8	6.4	8.9
Ohio	7.8	8.5	10.3	7.9	11.5
Cumberland	.4	.4	.5	.3	.5
Tennessee	.9	.9	1.3	.9	1.3
Southeast	5.8	7.6	1.0	7.9	11.8
Western Great Lakes	6.0	6.7	8.1	6.5	9.1
Upper Mississippi	4.6	5.0	6.1	4.5	6.7
Lower Mississippi	1.3	1.4	1.8	1.3	1.9
Upper Missouri	1.8	2.0	2.5	1.7	2.6
Lower Missouri	.9	.9	1.0	.7	.9
Upper Arkansas-White-Red	1.4	1.6	1.9	1.4	2.0
Lower Arkansas-White-Red	1.3	1.2	1.5	.9	1.3
Western Gulf	3.7	5.1	5.9	5.0	6.8
Rio Grande-Pecos	.5	.6	.7	.8	1.0
Colorado	.7	1.1	1.3	1.2	1.6
Great Basin	.5	.7	.8	.8	1.1
Pacific Northwest	2.2	2.8	3.3	3.0	4.3
Central Pacific	3.5	5.5	6.3	6.4	8.4
South Pacific	4.4	6.1	7.0	6.5	8.5
U.S. total	75.0	86.8	103.4	83.8	117.1

and 3. These are shown by States, regions, and selected metropolitan areas. These data are based on surveys of municipal sewerage and sewage treatment facilities undertaken by the Public Health Service in 1957. The estimates assume that by 1980 essentially all urban populations will be served by municipal sewer systems, and that this coverage will continue and apply also for the year 2000. It further assumes that the overall effective reduction in oxygen-demanding substances by sewage treatment processes, now approximately 44 percent for the Nation as a whole, will have increased by 1980 to an effective 70 percent. This 70 percent will result from a great increase in the number of secondary treatment plants and the virtual elimination of all raw sewage discharges through universal provision of primary treatment facilities. By the year 2000, the reduction of biochemical oxygen demand may increase to 80 percent, as a result of continued increase in the number of secondary sewage treatment plants.

TABLE 3.—*Projected municipal sewage loads from selected standard metropolitan areas within water resource regions*

[In terms of equivalent population]

[Millions of people]

Metropolitan area	1954	1980		2000	
		Medium	High	Medium	High
New England:					
Boston	1.8	1.3	1.5	1.1	1.4
Hartford	.3	.2	.3	.2	.3
Delaware and Hudson:					
Albany-Schnectady-Troy	.4	.3	.4	.3	.4
New York	10.3	8.5	9.6	7.2	9.4
Philadelphia	3.0	2.6	2.9	2.2	2.9
Eastern Great Lakes: Detroit	2.6	2.6	3.6	2.5	3.3
Chesapeake Bay:					
Richmond	.3	.4	.4	.4	.5
Washington	1.4	1.7	1.9	1.7	2.2
Western Great Lakes:					
Chicago	4.6	4.1	4.7	3.8	4.9
Lansing	.2	.2	.2	.2	.2
Ohio:					
Cincinnati	.8	.7	.8	.7	.9
Indianapolis	.5	.5	.5	.4	.6
Cumberland: Nashville	.3	.2	.3	.2	.2
Tennessee: Chattanooga	.2	.2	.2	.2	.2
Southeast:					
Birmingham	.5	.5	.5	.4	.5
Columbia	.1	.1	.2	.1	.2
Upper Mississippi:					
Cedar Rapids	.1	.1	.1	.1	.1
St. Louis	1.4	1.3	1.5	1.2	1.5
Lower Mississippi: New Orleans	.6	.5	.6	.4	.5
Upper Missouri:					
Denver	.5	.5	.6	.4	.6
Sioux City	.1	.1	.1	.1	.1
Lower Missouri: Kansas City	.7	.6	.7	.5	.8
Upper Arkansas-White-Red:					
Amarillo	.1	.1	.1	.1	.1
Oklahoma City	.3	.3	.3	.3	.3
Lower Arkansas-White-Red:					
Little Rock	.2	.2	.2	.1	.1
Western Gulf:					
Dallas	.6	.7	.8	.7	1.0
Fort Worth	.3	.4	.4	.5	.6
Houston	.8	.9	1.1	.9	1.3
San Antonio	.5	.6	.6	.6	.7
Rio Grande-Pecos: Albuquerque	.1	.2	.2	.2	.3
Colorado:					
Grand Junction	.1	.1	.1	.1	.2
Phoenix	.3	.5	.6	.6	.8
Pacific Northwest:					
Portland	.6	.7	.7	.7	.9
Spokane	.2	.2	.2	.2	.3
Great Basin: Salt Lake City	.2	.3	.3	.3	.4
Central Pacific: San Francisco	2.1	2.1	3.1	3.1	4.6
South Pacific: Los Angeles	4.2	5.6	6.4	6.1	8.0

On the basis of the medium rate of population growth, the population equivalents of the estimated stream loadings from domestic sewage plus wastes from city-located industries is estimated to be as follows:

		1954	1980	2000
Population served	million	100	192.6	279.4
Industries served	million P.E.	36	96.8	139.7
Total municipal load	do	136	289.4	419.1
Removal of BOD	percent	44	70.0	80.0
Residual BOD to stream	million P.E.	75	86.8	83.8

The industrial portion of the total municipal discharge to streams amounts to 27, 35, and 35 percent, respectively, for each of the 3 years indicated. In addition, there are also oxygen-demanding industrial wastes which are discharged directly into streams. No data equivalent to that for municipal sewage is available for this category of pollution, but it is conservatively estimated to at least equal the pollution load discharged from municipal sewers and sewage treatment plants. A more detailed statement on this source of pollution is provided later in the general discussion of industrial pollution. Based on the foregoing estimates, however, it appears that the Nation's water resources in 1954 were being subjected to an oxygen-demanding pollution load equivalent to discharging the raw sewage from approximately 150 million peopl This is expected to increase to 174 million by 1980 and then drop slightly to 168 million by the year 2000, as construction of treatment facilities continues to increase. Should the high rate of population growth prevail, these figures would be substantially higher.

It was estimated by the State sanitary engineers in 1955 that the streams of the Nation, at existing stages of dry weather flow and degree of regulation, could assimilate approximately 36 million population equivalents of oxygen-demanding wastes from municipal sewer systems and still maintain stream conditions acceptable to State water pollution control agencies. However, in view of the increasing pressure on our water resources to serve additional people and uses, it is now certain that the degree of treatment visualized in this 1955 evaluation cannot provide water of satisfactory quality to meet these emerging needs. Furthermore, the stream assimilative capacity cited above is a national average figure and specific areas in various parts of the country are or may become overloaded to the point where their capacity to assimilate wastes will be exceeded. Our waters are now receiving approximately twice as much pollution from municipal systems alone as was considered allowable in 1955. If the higher rate of population growth should occur, the situation could become worse, even with accelerated pollution abatement. This statement must, of course, be qualified by consideration of the degree of water quality improvement attainable through additional storage and streamflow augmentation. However, it should nevertheless be emphasized that dilution is no solution to the pollution problem.

Volume and strength of municipal sewage.—The volume of municipal sewage flow is roughly equal to the water consumed by municipal populations and industries. The relationship will vary widely depending upon conditions, however. For example, arid Denver produces a sewage flow representing 65 percent of the water used, while humid Milwaukee and Cleveland produce 120 percent more sewage flow than water used. Water losses from lawn sprinkling, street washing and water-main leakage are often counteracted by ground water infiltration and superimposed flow of sewage and industrial wastes from outlying areas using a separate water source. In the future there will be a greater degree of accounting for the water pumped into water mains, with frequent checks against leakage. There will be further reduction in sewage flow as improvement in pipe joint design and construction materials plus more judicious location of interceptors reduce ground water infiltration. Sewage flows for the period covered by this report are conservatively estimated on the basis of the medium rate of population growth to be as follows (in billion gallons per day):

1954	16.7
1980	28.6
2000	42.5

Several factors will tend in the future to increase the strength and volume of municipal sewage. The increasing use of garbage grinders will be one important factor. Sewage strength is likely also to increase because a greater percentage of industrial wastes will reach municipal systems. This will occur through the engulfing of the "industrial parks' and "industrial campuses" that are being located in the outer rings of metropolitan areas. Many of these now have their own treatment units as well as water supplies. Inducement for discharging industrial wastes into the municipal system will become strong, as industrially owned treatment facilities reach obsolescence and greater volumes of domestic sewage become available for diluting these industrial wastes. However, more municipalities will undoubtedly demand pretreatment of those industrial wastes that may tend to corrode or erode sewers, pumps, and treatment

facilities or are incompatible with or interfere with their treatment processes. Such pretreatment will also protect against poisonous or other industrial substances that may upset or interfere with sewage treatment processes. As more municipalities impose tax or other surcharges for treatment of high volume or high strength industrial wastes, however, the industrial load on municipal treatment facilities may ultimately decrease somewhat because of pretreatment and other factors.

Costs of municipal sewerage services.—Tables 4 to 9, inclusive, contain data on the annual and per capita costs of collecting and treating municipal sewage. The data are broken down by water resource regions and by metropolitan areas and States. They give total annual costs in millions of dollars and cost per person per year in dollars. The data include the cost of operation and maintenance as well as amortization.

These data indicate that the total annual cost of maintaining, operating, and paying for the facilities functioning in 1954 amounted to $476.5 million. This amounted to an average per capita cost of $4.26 per year. It is expected that the current backlog of needed additional facilities will have been constructed well before 1980 and that in that year approximately $818 million will be spent for the collection and treatment of sewage. The average per capita cost in that year is esti-

TABLE 4.—*Projected total annual cost of collection and treatment of municipal sewage in continental United States, by States*

[Millions of dollars]

[Includes operation, maintenance and amortization of investment]

	1954	1980	2000
U.S. total	476.5	817.6	1,200.6
Alabama	4.9	8.5	12.9
Arizona	1.2	3.6	6.4
Arkansas	1.8	2.4	3.2
California	44.3	101.4	167.1
Colorado	2.5	5.2	7.8
Connecticut	7.6	14.0	21.8
Delaware	1.2	2.3	3.4
District of Columbia	4.4	6.1	8.8
Florida	15.9	44.2	75.3
Georgia	6.2	11.5	18.1
Idaho	1.3	2.5	4.1
Illinois	33.5	36.5	86.0
Indiana	12.1	21.9	34.8
Iowa	3.7	6.1	9.3
Kansas	4.0	7.2	11.3
Kentucky	2.9	5.0	7.8
Louisiana	3.9	8.2	13.4
Maine	2.1	3.7	5.7
Maryland	10.5	23.2	30.1
Massachusetts	13.3	20.5	30.7
Michigan	25.2	46.0	72.3
Minnesota	5.8	10.3	16.3
Mississippi	2.1	3.5	5.4
Missouri	13.8	17.8	26.7
Montana	1.1	2.1	3.4
Nebraska	1.5	2.7	4.1
Nevada	.4	1.3	2.2
New Hampshire	1.3	2.1	3.0
New Jersey	22.2	41.6	55.0
New Mexico	.8	1.8	3.1
New York	58.6	92.3	139.1
North Carolina	6.0	11.0	17.9
North Dakota	.5	.8	1.3
Ohio	29.7	52.2	81.5
Oklahoma	2.2	3.6	5.2
Oregon	3.3	6.3	10.4
Pennsylvania	36.4	54.5	79.3
Rhode Island	3.4	5.9	8.9
South Carolina	3.4	6.7	10.8
South Dakota	.7	1.2	1.9
Tennessee	5.6	9.7	15.1
Texas	10.7	23.1	36.8
Utah	1.5	3.0	4.9
Vermont	.6	.8	1.4
Virginia	6.7	14.5	23.9
Washington	7.1	14.5	23.9
West Virginia	3.4	5.2	7.9
Wisconsin	11.6	19.7	29.8
Wyoming	.5	1.0	1.6

NOTE.—Sums of figures for the individual States will not add to the totals for the United States because of the different bases used in computing these 2 sets of figures.

TABLE 5.—*Projected annual cost per person for collection and treatment of municipal sewage in continental United States, by States*

[Dollars]

[Includes operation, maintenance and amortization of investment]

	1954	1980	2000
U.S. total	4.26	4.24	4.30
Alabama	3.26	3.11	3.06
Arizona	1.92	1.63	1.60
Arkansas	2.75	3.01	3.10
California	4.16	3.82	3.77
Colorado	2.46	2.15	2.14
Connecticut	4.25	4.18	4.22
Delaware	4.75	4.83	4.30
District of Columbia	5.25	6.02	6.29
Florida	6.56	5.34	5.21
Georgia	3.50	3.29	3.24
Idaho	4.63	4.44	4.37
Illinois	4.58	4.54	4.57
Indiana	4.55	4.45	4.43
Iowa	2.79	2.91	2.93
Kansas	3.56	3.46	3.46
Kentucky	2.51	2.64	2.71
Louisiana	2.25	2.24	2.26
Maine	4.25	4.27	4.27
Maryland	5.81	5.20	5.17
Massachusetts	3.25	3.81	3.76
Michigan	4.75	4.29	4.13
Minnesota	3.25	3.33	3.40
Mississippi	3.25	3.37	3.46
Missouri	5.07	6.20	6.26
Montana	3.75	3.68	3.67
Nebraska	2.25	2.25	2.25
Nevada	2.70	2.38	2.33
New Hampshire	4.25	4.63	4.70
New Jersey	4.75	4.79	4.90
New Mexico	1.75	1.59	1.56
New York	4.25	4.57	4.72
North Carolina	3.83	3.73	3.72
North Dakota	2.75	2.78	2.81
Ohio	4.65	4.59	4.58
Oklahoma	1.84	1.90	1.96
Oregon	3.57	3.49	3.46
Pennsylvania	4.65	4.88	4.87
Rhode Island	5.34	5.36	5.56
South Carolina	3.67	3.36	3.27
South Dakota	2.75	2.74	2.67
Tennessee	3.50	3.57	3.55
Texas	1.81	1.70	1.70
Utah	2.70	2.43	2.36
Vermont	4.25	4.79	4.82
Virginia	3.79	3.43	3.38
Washington	4.20	4.01	3.98
West Virginia	4.68	5.32	5.53
Wisconsin	5.25	5.07	4.95
Wyoming	3.25	3.14	3.11

NOTE.—Averages for the United States will not equal the averages of the figures shown for the individual States because of the different bases used in computing these 2 sets of figures.

TABLE 6.—*Projected total annual cost of collection and treatment of municipal sewage in continental United States, by water resources regions*

[Includes operation, maintenance, and amortization of investment]

[Millions of dollars]

River basin	1954	1980		2000	
		Medium	High	Medium	High
New England	27.1	39.1	45.7	53.6	73.9
Delaware and Hudson	95.2	152.0	172.4	214.6	278.1
Chesapeake Bay	30.1	53.3	61.0	81.2	106.3
Eastern Great Lakes	58.2	96.1	109.3	140.9	187.4
Ohio	40.0	66.0	76.3	96.5	130.5
Cumberland	2.1	3.3	3.8	4.5	6.4
Tennessee	4.9	8.0	9.5	11.3	15.8
Southeast	38.5	70.7	82.9	108.8	147.7
Western Great Lakes	49.3	88.0	92.8	119.1	159.0
Upper Mississippi	27.8	45.5	52.6	65.6	88.8
Lower Mississippi	6.5	10.6	12.3	14.9	20.0
Upper Missouri	7.8	13.0	15.1	18.2	25.0
Lower Missouri	3.3	5.0	5.7	6.6	8.9
Upper Arkansas-White-Red	4.5	7.5	8.5	10.4	13.6
Lower Arkansas-White-Red	3.6	5.4	6.2	6.9	9.0
Western gulf	10.0	19.0	21.1	28.5	35.5
Rio Grande-Pecos	1.2	2.3	2.6	3.9	4.9
Colorado	1.9	4.0	4.6	6.6	8.4
Great Basin	1.9	3.8	4.3	6.4	8.1
Pacific Northwest	13.0	23.7	27.2	38.3	50.6
Central Pacific	17.9	39.1	44.1	66.2	84.8
South Pacific	31.5	62.1	67.6	97.7	117.5
U.S. total	476.5	817.6	925.8	1,200.6	1,580.3

TABLE 7.—*Projected annual cost per person for collection and treatment of municipal sewage in continental United States, by water resources regions*

[Dollars]

[Includes operation, maintenance, and amortization of investment]

River basin	1954	1980		2000	
		Medium	High	Medium	High
New England	3.76	4.35	4.19	4.92	4.68
Delaware and Hudson	5.22	5.39	5.29	5.77	5.64
Chesapeake Bay	4.77	4.59	4.39	4.61	4.36
Eastern Great Lakes	6.40	6.40	6.28	6.58	6.33
Ohio	3.45	3.51	3.33	3.67	3.40
Cumberland	3.47	3.67	3.46	4.11	3.53
Tennessee	3.50	3.62	3.39	3.90	3.59
Southeast	4.48	4.18	3.91	4.12	3.75
Western Great Lakes	5.48	5.90	5.18	5.51	5.23
Upper Mississippi	4.09	4.11	3.90	4.37	4.00
Lower Mississippi	3.25	3.30	3.06	3.47	3.12
Upper Missouri	2.89	2.95	2.75	3.14	2.84
Lower Missouri	2.50	2.65	2.59	3.02	2.86
Upper Arkansas-White-Red	2.14	2.14	2.03	2.26	2.09
Lower Arkansas-White-Red	1.89	2.02	1.89	2.30	2.15
Western Gulf	1.81	1.68	1.61	1.69	1.58
Rio Grande-Pecos	1.75	1.66	1.53	1.57	1.45
Colorado	1.90	1.68	1.63	1.64	1.56
Great Basin	2.70	2.53	2.38	2.45	2.25
Pacific Northwest	3.91	3.83	3.68	3.79	3.54
Central Pacific	3.44	3.18	3.13	3.12	3.04
South Pacific	4.85	4.57	4.36	4.50	4.14
U.S. total	4.26	4.24	4.03	4.30	4.05

mated to be $4.24. By year 2000 the total annual costs may be in the neighborhood of $1.2 billion, or $4.30 per capita.

Expenditures of the funds cited in these projections are not expected to result in the satisfactory reduction in our streams of this form of pollution from municipal sources. Despite construction and operation of a large number of secondary treatment plants, a nationwide average level of sewage purification of only 70 percent BOD removal will have been attained. The residual pollution load from municipalities in 1980 will, on the average, still be about 2.5 times the amount which can be allowed if our streams and rivers, at their present stage of flow regulation, are also to serve other uses. Specific areas will, of course, be much worse.

What would be the cost in 1980 of providing treatment that would reduce the national pollution load to the level of 36 million population equivalents? Insufficient data are available to provide a firm answer. However, it may be speculated that if 88 to 90 percent sewage purification can be

TABLE 8.—*Projected total annual cost of collecting and treating municipal sewage in selected standard metropolitan areas within water resources regions*

[Millions of dollars]

[Includes operation, maintenance and amortization of investment]

Metropolitan area	1954	1980		2000	
		Medium	High	Medium	High
New England:					
Boston	7.8	11.3	13.0	15.6	21.0
Hartford	1.6	2.5	2.8	3.4	4.6
Delaware and Hudson:					
Alb-Schdy-Troy	3.5	5.6	6.4	7.9	10.7
New York	94.3	139.0	155.7	191.0	246.1
Philadelphia	21.2	31.7	35.3	43.5	55.3
Eastern Great Lakes: Detroit	16.4	26.9	29.7	39.0	48.6
Chesapeake Bay:					
Richmond	2.0	3.7	4.1	5.5	6.7
Washington	9.7	14.2	20.3	27.5	35.0
Western Great Lakes:					
Chicago	34.9	53.5	50.6	77.0	100.9
Lansing	10.9	1.7	2.0	2.7	3.6
Ohio:					
Cincinnati	3.5	5.8	6.5	8.3	10.7
Indianapolis	2.9	5.0	5.7	7.2	9.9
Cumberland: Nashville	1.3	1.8	2.0	2.4	3.0
Tennessee: Chattanooga	1.1	1.8	2.1	2.5	3.5
Southeast:					
Birmingham	2.1	3.2	3.4	4.5	5.4
Columbia	.6	1.1	1.2	1.6	2.1
Upper Mississippi:					
Cedar Rapids	.3	.5	.6	.7	1.0
St. Louis	8.6	13.8	15.6	19.4	25.4
Lower Mississippi: New Orleans	1.7	2.6	2.9	3.4	4.3
Upper Missouri:					
Denver	1.6	2.7	3.1	3.8	4.8
Sioux City	.3	.4	.5	.5	.7
Lower Missouri: Kansas City	4.2	6.8	7.5	8.9	11.4
Lower Arkansas-White-Red: Little Rock	.6	.8	.9	1.0	1.2
Upper Arkansas-White-Red:					
Amarillo	.2	.4	.4	.5	.7
Oklahoma City	.7	1.3	1.5	1.7	2.2
Western Gulf:					
Dallas	1.4	2.7	3.0	4.1	5.0
Fort Worth	.8	1.6	1.8	2.5	3.1
Houston	1.8	3.6	4.0	5.5	6.8
San Antonio	1.1	2.2	2.4	3.3	4.1
Rio Grande-Pecos: Albuquerque	.3	.7	.8	1.2	1.4
Colorado:					
Grand Junction	.3	.6	.6	.1	.1
Phoenix	1.2	2.8	3.1	4.5	5.7
Pacific Northwest:					
Portland	2.1	3.7	4.1	5.7	7.2
Spokane	1.1	1.8	2.0	2.7	3.5
Great Basin: Salt Lake City	.8	1.5	1.7	2.3	3.0
Central Pacific: San Francisco	4.0	8.1	9.1	13.7	17.4
South Pacific: Los Angeles	28.3	59.3	64.5	95.6	114.8

TABLE 9.— *Projected annual cost per person of collecting and treating municipal sewage in selected standard metropolitan areas within water resource regions*

[In dollars]

[Includes operation, maintenance, and amortization of investment]

Metropolitan area	1954	1980		2000	
		Medium	High	Medium	High
New England:					
Boston	$3.25	$3.86	$3.87	$4.44	$4.58
Hartford	4.25	4.62	4.56	5.09	5.17
Delaware and Hudson:					
Albany-Schenectady-Troy	6.40	7.49	7.50	8.29	8.66
New York	6.84	7.38	7.26	8.01	7.88
Philadelphia	5.31	5.52	5.39	5.87	5.70
Eastern Great Lakes: Detroit	4.65	5.66	4.47	4.64	4.42
Chesapeake Bay:					
Richmond	4.75	5.64	5.88	4.50	4.21
Washington	5.25	3.81	4.77	4.92	4.77
Western Great Lakes:					
Chicago	5.59	5.82	5.77	6.13	6.14
Lansing	4.75	4.68	4.73	5.09	5.18
Ohio:					
Cincinnati	3.45	3.57	3.52	3.81	3.78
Indianapolis	4.55	4.75	4.72	5.03	5.23
Cumberland: Nashville	3.50	3.61	3.45	3.97	3.66
Tennessee: Chattanooga	3.50	3.72	3.76	4.33	4.50
Southeast:					
Birmingham	3.26	3.19	3.05	3.21	2.97
Columbia	3.67	3.67	3.56	3.67	3.54
Upper Mississippi:					
Cedar Rapids	2.79	2.97	2.97	3.20	3.17
St. Louis	4.52	4.61	4.58	5.00	4.98
Lower Mississippi: New Orleans	2.25	2.36	2.33	2.59	2.53
Upper Missouri:					
Denver	2.46	2.47	2.42	2.68	2.62
Sioux City	2.79	3.39	3.21	3.83	3.93
Lower Missouri: Kansas City	4.58	4.80	4.80	5.43	5.46
Lower Arkansas-White-Red: Little Rock	2.75	2.73	2.68	3.21	2.81
Upper Arkansas-White-Red:					
Amarillo	2.14	2.08	1.94	2.17	2.06
Oklahoma City	1.84	1.87	1.82	2.02	1.94
Western Gulf:					
Dallas	1.84	1.68	1.62	1.67	1.56
Fort Worth	1.81	1.66	1.59	1.66	1.56
Houston	1.81	1.69	1.64	1.71	1.62
San Antonio	1.01	1.71	1.68	1.74	1.67
Rio Grande-Pecos: Albuquerque	1.75	1.59	1.54	1.57	1.48
Colorado:					
Grand Junction	1.90	1.50	1.50	1.77	1.73
Phoenix	2.61	2.28	2.27	2.25	2.16
Pacific Northwest:					
Portland	2.50	2.54	2.40	2.58	2.49
Spokane	4.20	4.25	4.15	4.28	4.15
Great Basin: Salt Lake City	2.46	2.36	2.31	2.32	2.27
Central Pacific: San Francisco	1.45	1.37	1.35	1.34	1.32
South Pacific: Los Angeles	5.02	4.74	4.62	4.68	4.30

achieved by the large cities of the future the goal may be attained—providing industry is able to provide equivalent parallel treatment of its wastes. If this level of treatment could be consistently achieved the cost figures for collection and treatment of municipal sewage would be increased to about $6 per person per year, or only slightly less than two-thirds of the cost per person for providing municipal water supply.

As was pointed out above, however, even such a level of stream purification will probably still not be sufficient.

2. *Infectious agents*

These are disease-causing organisms which are carried into streams, lakes, and ground water sources by wastes from municipalities, sanatoria, and certain kinds of industries, such as tanning and slaughtering plants, which contain human and animal wastes. These organisms can cause the occurrence of diseases such as typhoid fever, or various virus infections and intestinal disorders in persons ingesting them either directly by drinking the untreated water, or indirectly through recreational and other activities.

It has been demonstrated that effective treatment followed by disinfection will, in addition to reducing the oxygen demands of sewage effluents, also markedly reduce the number of disease organisms in these effluents but the resulting effluents may still contain a portion of each kind of the microorganisms which were present in the raw sewage. The concentration of these surviving disease producers and their persistence in the receiving streams are dependent upon numerous factors, such as the amount of exposure to sunlight, the degree of dilution and the physical and chemical characteristics of the receiving waters. Under winter conditions the relative concentrations of these bacteria in large rivers receiving sewage will be reduced approximately 90 percent after 2 days flow and 95 percent after 4 days flow. Under summer conditions the reductions may be greater. Organisms causing enteric disorders have been repeatedly isolated from river waters throughout the United States, as well as other areas of the world. Tuberculosis bacteria have been demonstrated in streams as much as 3.5 miles downstream from the point of discharge of sanitoria wastes.

Although the transmission of infectious diseases by treated water is apparently infrequent, the presence of infectious disease agents in polluted surface waters represents a potential danger to participants in aquatic sports and to other users of the raw waters. Disinfection of treatment plant effluents and other wastes before discharge into public water bodies, by means of chlorine or other substances substantially reduces this danger.

3. *Plant nutrients*

Plant nutrients are mineral substances in solution which are used as food by aquatic plant life, such as the algae and water weeds normally found in streams and lakes. Nitrogen and phosphorus are the two elements principally involved. These

occur to some extent in streams under natural conditions but are introduced in much larger quantities by discharges of municipal sewage and some industrial wastes. These substances are also leached or washed from farmlands in increasing quantities as agricultural use of chemical fertilizers expands.

Nutrients having their origin in sewage are stable mineral compounds remaining in solution after the oxygen demanding organic wastes are removed by treatment. They are a serious problem because they are not removed by ordinary sewage treatment processes. Desalination, the only practicable treatment process available other than direct consumption and removal by aquatic plants, is far too expensive for general application today.

These nutrients in solution are fertilizers, and stimulate intensive and extensive growths of water plants, which when they die and decay, cause secondary oxygen-demanding pollution in the receiving waters, accompanied by disagreeable tastes and odors. These tastes and odors detract from reuse of the water for municipal purposes unless expensive additional treatment is provided to remove them. Our concern over these substances stems therefore from a need to maintain a balanced aquatic environment which will permit maximum beneficial use of available water resources.

No attempt has been made to estimate quantitatively the nutrient segment of the national pollution load. Sufficient data are not available for this purpose. It seems prudent however, to indicate that the threefold increase in municipal pollution loadings by year 2000, plus the additional loadings anticipated from independent industries, will almost inevitably result in a comparable increase in nutrients transported to streams via treated sewage effluents. Furthermore, the higher degree of sewage treatment now being provided will render these compounds more readily available to plant life. Plant nutrients from fertilizers can also be expected to increase substantially as a result of more widespread application of improved farming techniques.

The effects of nutrient-laden waters will be the increased frequency of algae "blooms" in water impoundments accompanied by intensified taste and odor problems at water-treatment plants, the unnatural green-soup appearance of streams and lakes, the death of fish, the strong odor of decaying windrows of accumulated dead aquatic plants on shorelines, and interference with boating, water skiing, and swimming. It was the possibility of the occurrence of this situation in the Potomac River which prompted Dr. Abel Wolman to recommend to the Interstate Commission on the Potomac River in 1958 that the treated sewage effluents from the District of Columbia area eventually be transported to the Chesapeake Bay where a greater volume of diluting water is available than in the Potomac River.

Not the least of the nutrient problems of the future is the possibility of toxic reactions developing in water supply sources resulting from the high density growth, death, and decay of certain types of algae. A poison generated in some algae accumulations, which resembles strychnine, has on occasions killed ducks, sheep, dogs, and cattle that have consumed such water.

On the positive side, green plant life converts these residual waste products of civilization eventually into dissolved oxygen. It is possible therefore that, in the future, the nutrient balance in streams and lakes will be carefully controlled by water pollution control agencies to promote the controlled manufacture of dissolved oxygen. In this manner the streams may be better able to successfully assimilate the treated sewage and industrial wastes. It is more likely however, that criteria for the plant nutrient content of treated wastes will eventually be established as a basis for maintaining stream-water quality. This in turn may lead to the purposeful growth of algae in treatment plant effluent "polishing ponds". Here oxygen would be manufactured by algae and in the process, the plant nutrients would be removed from solution. The algae might, in turn, be harvested and converted to animal and possibly human food products.

4. Organic chemical exotics

A water pollution problem of great concern, which will increase manyfold in significance in the future, is caused by discharges of certain synthetic organic chemicals in our water bodies. These chemicals include such substances as the detergents used in household washing and laundering

and the new insecticides, pesticides, and weed killers which are now receiving increasingly widespread usage in agriculture.

Evidences of these chemicals have been found in many of our streams and lakes. Some examples of these materials are given below:

Material	Findings
DDT [1]	Found in concentrations of 5 to 20 parts per billion in the Detroit, Missouri, Mississippi, and Columbia Rivers.
Aldrin [1]	A chlorinated insecticide found in the Snake River, about 1 part per billion.
O-nitrochlorobenzine	A byproduct of organic chemical manufacture. Found to persist in the Mississippi River for 1,000 miles, at concentration of 1 to 35 parts per billion.
Petroleum derivatives	Numerous materials associated with oil. Included are benzene compounds, oil, xylenes, naphtholene, pyridine.
Synthetic detergents	These materials are now present in most surface waters and in many ground waters. They foam if present in a concentration of 1 part per million.
Decomposition products	A great deal or organic contamination in water is from disintegration products of industrial and natural materials. Almost nothing is known about these materials.

[1] Examples of the various chlorinated hydrocarbons receiving intensive use as insecticides.

Detergents are carried into water bodies with domestic and industrial sewage. The insecticides, pesticides, and herbicides may be washed off vegetation and land surfaces by rain or irrigation water, or may be applied directly to these waters for control of pests or rough fish.

Other persistent substances are discharged with some industrial wastes. None of these substances are removed from water either by sewage treatment plants or water purification plants to a satisfactory extent.

These organic chemicals are relatively new, and their effects upon human beings, animals, and fish and wildlife are as yet little understood. The greatly expanded use of organic insecticides since the advent of DDT in 1944 has created new problems in water pollution. There now are more than 100 synthetic organic insecticides on the market and these are available in thousands of different formulations.

More than 30 million acres of cultivated cropland are sprayed one or more times annually in the United States. Ariel spraying is increasing. The treatment of such noncroplands as forests and highway rights-of-way, is adding to the total use of insecticides, pesticides, and herbicides. In addition, the chemical control of rough fish, aquatic vegetation, and nuisance plants such as mesquite is increasing.

Over 500 million pounds of synthetic organic pesticides and 1 million pounds of inorganic (arsenicals, copper and zinc sulfate, sodium chlorate, boron, and sulfur) are produced in the Nation annually. Farmers in the United States spent $231 million in 1957 for agricultural chemicals other than fertilizer.

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With this amount of highly toxic materials being broadcast over the land, it is inevitable that some of it will reach our water courses in concentrations which are toxic to aquatic life. They may be applied directly to the water, they may drift onto it during the treatment of adjacent areas, or they may be washed in from treated areas of the entire watershed. Many of these materials have a long residual toxicity in the soil. Numerous fish kills have been reported. Other aquatic life, both animal and vegetable, making up the food chain of fishes, has been wiped out.

Fish and Wildlife Service and Public Health Service experiments with various insecticides as toxicants to fish and small game indicate that there may be insidious consequences from prolonged exposure to small quantities of insecticides in small mammals and birds. Observations on quail indicated that a large percent of the eggs were infertile and chicks were often weak, resulting in a decimation of the population. Where the insecticides were introduced through the water environment, they seemed even more destructive to small game population, fish, snakes, and frogs.

Most pollutants can be traced to a point source in a stream. Insecticides, however, may have their source in an entire watershed. Moreover, pollutants of this type are not amenable to accepted means of treatment. Analysis of samples taken in connection with several Public Health Service investigations and the national water quality basic data program has shown the presence of insecticides in our major rivers. As the use of these chemicals increases health authorities are showing an increasing concern over possible long-term ingestion of these materials.

Intensive research by the Public Health Service has been underway since 1950, and field investigations by the Service to evaluate the effects of insecticides use on water resources were begun in August 1958, in the Southeastern States.

If serious pollution problems are to be avoided and if we are to preserve our water resources in many areas, it may be necessary to reverse the trend toward widespread general use of insecticides, and to concentrate on specific limited applications instead. The long-range goal may well have to be discovery or development of various benign insects and organisms as natural insect control agents, rather than use of these toxic chemicals for the purpose.

5. Other mineral and chemical substances

A large number of other mineral and chemical wastes result from various mining and industrial processes, or come from certain sources found in nature. They include a wide variety of substances such as common salt, metals, and metal compounds in solution or as very fine particles, acids, and a wide array of manufactured chemicals. Their effects upon human and animal life as well as upon various industrial and agricultural processes are equally varied and often not yet known or understood. Some have serious toxic effects. For convenience in discussing them, these various substances are subdivided into salt, acids, and other industrial chemicals.

Salts.—Pollution from common salt dissolved from natural deposits occurs to some degree in many areas but is a serious problem primarily in certain river basins of the Southwestern United States. This is especially true of the Arkansas and Red River Basin areas of Texas, Oklahoma, and Kansas. Salt is also troublesome in Arizona and other arid sections of the West. It is estimated that 15,000 tons of salt per day are discharged into the otherwise satisfactory waters of the Arkansas and Red River Basins. During the recent drought period, when streamflows were at their lowest, concentration of salt in Lake Texoma on the Red River reached such levels that Dallas, Fort Worth, and other cities were prevented from tapping this otherwise acceptable lake as a badly needed auxiliary source of water.

One source of salt pollution in this area is brine discharged with oil as it is pumped from the ground. A program for the reinjection of these brines into the underground strata is becoming effective, however. The big problem in the area is the salt discharged from seeps and solution areas. The Public Health Service is now engaged in an extensive study of the whole water quality problem of the Arkansas-Red River Basin area, looking toward a solution to the difficulties arising from salt pollution.

Other areas where various mineral salts such as sulfates are serious problems are the Salt River Basin in Arizona, and certain other western river valleys where the return flows from irrigation carry with them heavy concentrations of these salts leached from the soil. Unless some new technique for applying irrigation water to farmlands is developed, the problems here are those of producing sufficient diluting waters to permit reuse of the return flows, or of developing economical means of desalting these waters.

Acids.—While acids are contained in many industrial wastes, the principal extensive source of acid as a water pollutant is drainage from coal mines. Sulfuric acid is formed at exposed surfaces in coal mines where sulfur-bearing minerals, water, and air come into contact. Water flowing through mines or pumped to the surface carries acid to the receiving streams. Acid mine drainage problems are generally confined to the more humid coal regions east of the Mississippi River. More than 90 percent of all acid mine drainage occurs in the Ohio River Basin. In addition there are serious acid mine drainage problems in the upper watersheds of the Potomac, Delaware, and Susquehanna Rivers and some of the tributaries of the Mississippi River in Illinois.

The magnitude of the problem is indicated by a Public Health Service estimate in the early 1930's that 2.7 million tons of sulfuric acid were produced annually by mines. The distribution of the load was as follows:

Mine sources	Mines (total number)	Acid (tons per year)	Percent of total
Abandoned mines	16,300	1,200,000	44.4
Idle or marginal mines	3,400	250,000	9.3
Active mines	8,100	1,250,000	46.3
Total	27,800	2,700,000	100.0

This acid damages water quality by rendering streams acid and increasing hardness and mineral content, thereby making expensive and difficult

the treatment of the water for municipal and industrial purposes. At the same time these waters corrode all manner of concrete and steel structures. In addition, recreational values are reduced and biological stream self-purification processes are altered. Aquatic life may, in the more serious situations, be destroyed.

In 1940 the measurable tangible damages were estimated at more than $2 million annually. By 1960 it was estimated that damage would amount to $4 million to $5 million per year.

Many mines were sealed in the 1930's with the help of unemployed persons engaged in relief work, and at the end of 1940, acid discharge had been reduced to an estimated 1,822,000 tons per year. However, many seals have now become ineffective, and acid production has also increased in active mines by the extension of some workings and abandonment of others. Some improvement has been achieved by augmenting normal low streamflows with releases of neutral or alkaline waters from reservoirs. Nevertheless, the number of miles of major streams and their tributaries still affected runs into the thousands.

Present information indicates that a large measure of correction of mine acid problems could result from a comprehensive control program involving the following measures:

1. Provision for inspection and maintenance of existing satisfactory air seals and for future mine sealing programs.
2. Provision of reservoir capacity for flow regulation to reduce acid concentrations.
3. Inauguration of an aggressive program of mine sealing with any existing restrictions modified as necessary.
4. Adaptation of the better mining methods to acid control.
5. Sealing exposed mine surfaces with impervious clay layers, thus preventing oxidation by air contact.
6. Development of better drainage systems for all types of mines, including surface and ground water diversion, where practical.
7. Development of recreational lakes from abandoned strip mines.
8. Backfilling of strip mines when 7 is impractical.
9. Prevention of sulfuritic material oxidation by application of inhibitors.
10. Clarification of laws governing mine drainage to facilitate the comprehensive program.

Special research and investigations are also needed to develop suitable methods for—

1. Inhibition of oxidation by use of chemicals.
2. Reclamation of the acid.
3. Biological treatment of acid wastes.

Other sources of acid pollution are largely found in industries and are usually much more local in their effects and are more directly controllable. These sources are discussed under the subject of industrial pollution following.

Other industrial chemicals.—Industries produce a wide variety of mineral and chemical pollutants. In addition, however, industries also produce substantial amounts of oxygen-demanding organic wastes and other pollutants. The industrial waste problem is so complex and includes wastes from so many of the categories of pollution discussed in this section, that a separate section of this report is devoted to the problem. This section begins on page 16 following the discussion of heat pollution under item 8.

6. Sediments

General statement of the problem.—Sediments are primarily soils and mineral particles washed from the land by storms and floodwaters. While sediments are not normally a primary concern of water pollution control agencies, they nevertheless have important bearings on water quality problems. Aside from filling stream channels and reservoirs, they make necessary expensive additional treatment processes for municipal and industrial water supplies and contribute to the problems involved in the assimilation of oxygen-demanding organic pollutants by streams and lakes. Sediments cause erosion of power turbines, pumping equipment, and other structures, reduce fish and shellfish population by blanketing fish nests, spawn, and food supplies, reduce the light required by green aquatic plants in the process of maintaining an adequate dissolved oxygen balance in water, and plug water filters.

Rough estimate of the suspended solids loadings reaching the Nation's streams from surface runoff shows these to be at least 700 times the loadings caused by sewage discharges. As an example of the magnitude of this problem, Wolman and Geyer, in their "Consultants Report to the Inter-

state Commission on the Potomac River Basin" (1958) stated that the most serious pollution problem of the Potomac River Basin is siltation. Although no actual measurements are available, "it has been guessed that the annual amount of silt carried by the river might be as much as 40 million cubic feet. In 1957, one flood alone was guessed to have brought down some 40 million cubic feet." Practically all of the silt settles in the tidal estuary at and below Washington. They concluded in an earlier 1957 report that "it is doubtful whether even the most complete erosion control program would reduce silt production by more than one-half".

Rough estimates of soil loadings are also available for other areas. The Corps of Engineers in 1952 estimated, for example, that the sediment yield of the Mississippi River watershed, above the delta, is about 500 million tons per year.

Possible reductions in stream sediment loads.—There are as yet no clear answers to the problem of reduction in sediment loads, but experience in some areas will indicate what might be accomplished in this regard under various conditions. Thus, it has been reported that universal application of practicable soil conservation measures in most agricultural watersheds east of the 100th meridian could reduce sediment production by from 50 percent to as high as 75 to 90 percent. West of the 100th meridian conditions are so varied, however, and existing data are so meager that it is hazardous to make any generalizations, but in some instances 75 percent reduction appears possible.

In summary, it is estimated that there are about 595 million acres of eroding land contributing importantly to flood damage and sediment deposition, but that installation of protective measures in the near future appears to be economically warranted on only about 297 million acres. Since there are about 1.9 billion acres of land area in the United States, the avoidable sediment load of the Nation involves at least one-eighth of the land area of the United States. The cost has been estimated at $6 billion and will require many years.

Future sediment problems and solutions.—Excessive sediment loadings on streams will probably continue for a number of decades, since watershed protection programs are mostly still in the planning stage and total cooperation from all segments of each watershed community may take many years to achieve. However, as more dams, both large and small, are constructed on the various rivers and tributaries, more and more sediment, both natural and man induced, will be trapped and settled out. Thus, whereas earlier water treatment problems were concerned with high turbidity, short filter runs, and variable chemical quality, future treatment will, as sediments are reduced, center more and more on such problems as tastes and odors caused by algae growths induced by sunlight penetrating the clarified waters. On streams such as the "Big Muddy" Missouri River, which are already being clarified, algae problems are beginning to show up. Such problems may well be more complex in their solution than those produced by sediments, which, on the positive side of the ledger, did at least serve to drag down a portion of the organic pollution contained in sewage and industrial wastes, thus aiding in stream self-purification.

As detention and impoundment reservoirs are constructed, the ultimate effect upon water quality will be that of a changing environment in which water will be clearer, extremes of high and low streamflow reduced in range, and, in general, a slowing of water velocity. Each of these factors will profoundly affect the interplay of physical, chemical, and biological factors involved in the assimilation by these water bodies of the wastes from city, industry, and farm. These factors will need to be evaluated.

7. *Radioactive substances*

Definition of the problem.—Radioactive substances which are possible sources of water pollution are produced from several sources. Waste products from mining and refining radioactive minerals such as uranium or thorium may wash or be discharged into streams. Waste products from the use of refined radioactive substances in power reactors or for industrial, medical, or other research purposes, can, if allowed to escape, also produce dangerous concentrations in the receiving streams. Radiation has serious harmful effects upon all human and animal life, and concentrations of these substances in water bodies must therefore not be allowed to rise above those relatively minute maximum amounts which are considered safe. The three major factors which determine the importance of any specific radioactive waste are: (*a*) The quantity of material involved, (*b*) the duration of

the waste discharge, and (*c*) the degree of hazard associated with the specific radioisotopes involved.

Quantities of radioactive materials.—In terms of source material, there are 25 uranium mills and refineries presently in operation or under construction, processing some 21,000 tons per day of uranium-bearing ores. The most hazardous radioisotope involved in this case is radium. Approximately 5,000 grams per year of radium are produced as wastes. Most of this, perhaps 98 percent, remains as insoluble radium tied up with the spent ore. However, the remaining fraction can, if allowed to leach or wash into water courses, result in serious water contamination, since the allowable concentration of this substance in drinking water is only 4 micro-micrograms per liter.[1]

The uranium mining industry has apparently gone through its major expansion phase and will probably increase at a much slower rate hereafter, but it is quite possible that the thorium processing industry may develop in the foreseeable future as a further source of nuclear fuel. Thus, it would appear that the problems of disposal of radioactive wastes from these sources can be expected to continue to grow for some years.

The utilization of the products and properties of refined radioactive fissionable materials has created an industry presently having a capital investment of about $7 billion. There is reason to believe that within the next 20 to 50 years there will be a relatively large increase in construction of nuclear reactors, especially for power purposes. Recent hearings before the Joint Congressional Committee on Atomic Energy indicate that by 1964 we can expect the reactor industry to have grown to the point where 10,000 megawatts of heat will be produced; by the year 2000 it is anticipated that this will increase to about 750,000 megawatts of heat. As the reactor industry grows, there must be a parallel expansion of the industry which processes spent fuel elements to reclaim fissionable material.

Unless technical breakthroughs provide needed new methods, it is possible that by the year 2000 the annual disposal of high-level or high-activity radioactive wastes from this industry can amount to a difficult and hazardous problem. Storage is the present temporary solution for the handling of these wastes, but the situation will become increasingly critical with growth of the industry since storage facilities are definitely limited. As commercial nuclear power capacity expands, the waste problem may prove the most difficult hurdle in the advancement toward broadscale peaceful use of atomic energy. The size of nuclear reactors is not necessarily the only criterion as regards safety, however, since even small, university research reactors can constitute a major radioactive waste disposal problem in terms of the capacity of the local environment to assimilate wastes. In contrast, most medical uses of radioactive isotopes, most radioactive tracer studies, which are infrequent, and the use of encapsulated sources are likely to constitute minor radioactive problems.

Duration of exposure from radioactive waste discharges.—The duration of exposure from radioactive discharges depends upon whether continuous processes or intermittent discharges such as radioactive tracer studies, are involved. Other factors determining the possible duration of exposures include the kind of emission (alpha, beta, or gamma), the half-life of the substance involved, and the relative sensitivity of the human organ affected to the material. As an example, radium, which has a long half-life, affects the bones and is considered to be much more hazardous than radioiodine, which is short lived and affects the thyroid gland. Thus, major radioactive waste problems may involve significant quantities of especially hazardous radioisotopes resulting from continuous processes, or minor problems resulting from infrequent discharge of small amounts of less hazardous radioactive elements. Obviously, the distinction may not be so clear cut in some cases, but consideration of the foregoing criteria will usually provide a satisfactory estimate of the relative importance of specific waste disposal problems.

Degree of hazard from radioactive substances.—Since exposure of human beings to radiation is cumulative over their respective lifetimes, the fundamental problem of radioactive waste control is the control of the total radiation exposure of human populations. There are in nature already a multiplicity of sources of human radiation exposure. Human populations may ingest or inhale radioactive materials in a wide variety of ways. In determining criteria for the disposal of radioactive wastes, one must therefore consider all means by which a local group is exposed to radiation. Thus, while exposure to radioactive wastes

[1] Recommendation of the National Committee on Radiation Protection and Measurement.

in water may be minor, such exposure is nevertheless of significance because it contributes to the total of accumulated exposure of the persons involved. In addition such wastes can, of course, be of sufficient strength to be a major danger in themselves.

In terms of allowable levels or concentrations of radioactive materials, we are entering a new era in waste control, since we are dealing with truly infinitesimal amounts of material. For example, the presently accepted maximum permissible concentration (MPC) of radium in a domestic water supply is 4.0 micromicrograms per liter; for strontium 90 the figure is about 0.5 micromicrograms per liter. These figures may be compared to the allowable amounts of common poisons such as arsenic or lead in the drinking water; for arsenic the allowable is 50 million micromicrograms per liter; for lead it is 100 million micromicrograms per liter. Thus, the allowable arsenic or lead content of drinking water is 10 million times the allowable radium content and 100 million times the allowable strontium 90 content. A further problem created when radioactive substances are allowed to get into water supply sources results from the fact that such substances are concentrated by aquatic growths and by sediments to a level many times in excess of the concentration present in the surrounding water.

Radioactive materials are characteristic of a newly developing class of water pollutants that are most difficult or impossible to detect by the human sense alone. Their presence or absence in water, food, or air must, therefore, be substantiated with the aid of delicate instruments. This characteristic, however, is also common to other types of industrial wastes, such as those arising in the petrochemical industry, and in itself does not require that radioactive waste control be administered in any unusual or special fashion. Essentially, the control of radioactive wastes from the nuclear industry is a problem in principle no different than the problem of controlling wastes discharged from other industries. While special means of detection and measurement peculiar to the materials are required, this is also very true of other pollutants and does not affect the administration of control measures.

Disposal of radioactive wastes.—Conventional water treatment plants in use today are not designed to provide protection against such small concentrations of such hazardous materials, nor is it likely that they will be easily or economically modified to do so. Rather, it appears that the only practical means of protection against excessive human exposure to radioactive wastes will be treatment and control of such wastes at their source before discharge to the environment. This is usually accomplished by providing long term, or permanent storage of the concentrated liquids containing these wastes.

Ultimate disposal methods utilized or being explored cover both land disposal and ocean burial. As regards land disposal, discharges into abandoned salt mines and other underground cavities or formations, at varying depths below the surface, are being studied. Prepared excavations in shale beds, or low-permeability areas with a clay content suitable for fixing radioisotopes in place, and other possible geologic repositories are under investigation. One of the difficulties about such methods of disposal, however, is that water or other mineral resources occurring near such underground disposal areas, which may be needed at some future time, may nevertheless be rendered permanently unavailable by radiation seeping or leaching into the strata or deposit. Ocean burial of heavily encased wastes in limited bottom areas has been effectively employed, radioactive materials so buried being small amounts of low-level wastes. Direct disposal by dilution in the ocean, however, occasions the possibility of reconcentration of specific fission products in marine organisms. Difficult equipment and transportation problems are also involved with this method of final disposal.

A further problem that must be faced with the developing nuclear industry involves the possibility of nuclear accidents. Although such accidents represent only a brief exposure period the amounts of radioactivity discharged into water sources could be massive and hence could constitute an important source of exposure. The most careful design and operation of nuclear reactors will undoubtedly prevent all but an occasional accident. However, these possibilities cannot be neglected.

In terms of both high and intermediate level wastes, it is expected that by 1964 private nuclear power facilities will have produced a total of over 1 million gallons of wastes which will have to be stored. With the anticipated large increase in electric powerplants, this figure could reach about 35 million gallons by 1980 and roughly 300 million

gallons by year 2000. Considering all other possible processes and uses for radioactive materials, the cumulative total of such wastes requiring storage in year 2000 may well be more than double this amount. The magnitude and cost of such a disposal problem suggests the need for a very substantial effort to find better methods of disposal or of utilization of these materials. Present disposal methods are reported to have already cost over $75 million. It is impossible, on the basis of present knowledge, to make a reasonable approximation of what these costs might total by year 2000.

8. Heat as a pollutant

Tremendous quantities of water are withdrawn daily from streams and lakes for cooling purposes by steam-electric powerplants, steel mills, petroleum refineries and various other industrial plants. After use, these waters are usually returned to the river or lake from which they were withdrawn. Substantial amounts of heat are thus transferred to these water bodies. Since the amount of oxygen which water can hold in solution diminishes with increasing temperature, the introduction of heat in any substantial quantities into such water bodies has the net effect of introducing additional pollution, because the ability of these water bodies to assimilate oxygen-demanding pollution, or to support fish life, is thereby reduced.

Heat also has a direct detrimental affect upon fish and other aquatic life because it changes their physical environment. Some fish can stand only a very few degrees of increase in temperature, and a substantial increase in temperature can result in the virtual elimination of all aquatic life.

Examples of stream difficulties resulting from introduction of excess heat are the Mahoning River in Ohio and the Illinois River near Chicago. In the former case, extensive use of the river for both industrial and power cooling in the Youngstown region raises the temperature of the river in the summer to such an intent that not only is fish life completely eliminated, but the river is rendered unfit for further use for either pollution assimilation or additional cooling.

In the case of the Illinois River, the effects of thermal pollution introduced by steam-electric plants is reported to be equivalent to the doubling of the organic waste load which the river now receives from the Chicago area.

Heat pollution from both industrial and powerplant sources can be expected to increase at a very substantial rate over the next 40 years. Industrial activity is projected to increase to somewhere between 5 and 10 times present rates, and heat pollution from this source can be expected to increase accordingly. Electric power generation has been almost doubling in capacity every 10 years. Projected to year 2000, this could mean at least a tenfold increase in power capacity. Allowing for improvements in the efficiency of the newer plants, this would still mean somewhere around an eightfold increase in thermal pollution. This situation will prevail whether the powerplant be the conventional fossil fuel burning plant or the newer nuclear energy powered plant, because cooling water is required for condensing spent steam in either case.

In certain now heavily populated and industrialized areas, such an increase in heat pollution of rivers and lakes could have a profound effect upon the pollution assimilating capacity of these water bodies, as well as upon their ability to meet satisfactorily the ever increasing demands for recreational facilities and fishing opportunities. Careful planning of the location of plants requiring cooling water will be necessary to minimize this heat pollution danger, and it may well be necessary to require recirculation, or spray pond, cooling tower, or air cooling methods as a means of reducing the amount of cooling water used in those instances where heat pollution would seriously interfere with these other uses of water.

Another effect of heat which results in the depletion of oxygen in stored water reservoirs and some natural lakes is caused by excessive summer temperatures, which heat up the surface layers of the lakes. Under these conditions, these water bodies tend to stratify, with cool water remaining undisturbed and uncirculated in the deeper portions of the lake. Decomposing vegetation depletes the dissolved oxygen in these lower strata, and fishlife then leaves the area. When such waters are discharged through the lower gates of reservoirs, the oxygen-deficient water may have a detrimental effect on the receiving stream, both with respect to its aquatic life and its ability to assimilate oxygen demanding pollution introduced downstream.

Stratified lakes tend to recover their oxygen content with the return of cold weather, but can

have a serious detrimental effect during summer months. Withdrawal of water from higher level gates during the hot months can correct this difficulty if such gates are provided for in the design and construction of the dam in the first place.

An excellent example of this problem is the situation on the Roanoke River, discussed in the appendix.

INDUSTRIAL WASTE PROBLEMS

General statement of the problem.—Industrial wastes include all of the eight categories of pollutants previously discussed. Of particular significance, however, is the fact that adequate criteria for evaluating some of them have not yet been developed. Up to now, oxygen demanders have generally been looked upon as the gage of water pollution, but this class of pollutants is only one of the types of pollutants contained in industrial waste discharges. Chemical, mineral and stable organic compounds (largely found in industrial wastes) are now coming to be of equal or greater significance in water pollution.

The biological processes for stabilizing oxygen demanding organic pollutants are well enough understood to permit empirical design of treatment facilities which can stabilize up to about 90 percent of these wastes, although it must be recognized that even this degree of treatment is inadequate in some situations. The treatment of this type of pollution is, therefore, in general no longer dependent upon the discovery of applicable techniques, although we still could use more economically designed plants. Elimination of most of this type of pollution can now be achieved at any time that the public believes that the resulting benefits in terms of providing suitable water for other purposes is sufficiently important to warrant the necessary action. The costs involved, while substantial, are not unreasonable.

The same situation is not necessarily true of pollution from the chemical and mineral substances being produced by industry. A broad group of these waste products remain relatively stable or are reduced in nature so slowly as to be classified as virtually stable. These pollutants are legion and their numbers are increasing with our technological developments. They include chemical wastes, petrochemicals, salt brines, acids, silt, sludges, and radioactive materials. Many of these substances are toxic. Many of them were not known a few years ago, and neither the methods of removing them from water or their effects upon people or other processes are yet understood. In addition, about 400 new chemical substances are created each year by industrial research. Through ever-increasing use, many of these are finding their way into our water sources, and the problems posed are, to say the least, puzzling. Thus, pollution associated with industrial development takes on a special significance.

Projected industrial activities.—The index of industrial activity stood at 125 in 1954. By 1980, at the medium level of growth, this index may stand at 355 and, by the year 2000, is estimated to reach 767. At the high rate of growth the index could reach 437 in 1980 and 1,180 by year 2000.

A large proportion of this expected industrial expansion will be in industries using the common wet-process extracting and manufacturing methods. This portends a very large increase in the stream polluting possibilities of such industries, with a further potential deterioration in the quality of water resources. Projections for particular industries are discussed below.

The food industry, generally well distributed over the country, will more than double production by the year 2000. The waste water discharged from food processing is essentially oxygen demanding in character and amenable to known treatment processes. The future treatment problem will be more complete removal of pollutants, particularly those that cause enrichment of the receiving waters leading to excessive algae growths.

The pulp and paper industry projection shows a possible eightfold increase. Wastes from this industry vary with type of process; pollutants include lignins, lost pulp, processing chemicals and color. Considerable progress in the control of these wastes has been made, and future activity in this direction will continue. The recent movement into the South is well known and future moves to the Rocky Mountain sections of Montana, Wyoming, and Colorado may be expected. Existing operations in Maine, Wisconsin, Minnesota, Washington, and Oregon will expand.

The iron and steel industry will increase production sixfold. Its waste waters include such pollutants as acids, toxic chemicals, iron salts and heat. Rapid strides have been taken by this industry through inplant control, to reduce the volume of water required per ton of product and

to reduce waste discharges. Progress along these lines will continue. Generally, the location of these plants will be limited to locations convenient to sources of raw materials (such as coal, limestone, iron ore) and to transportation.

Aluminum production increase is projected nineteenfold. Its process wastes include cooling waters, alkalines, and miscellaneous wastes. Considerable progress may be expected through inplant water control to reduce wastes and heat losses from this industry.

Chemical products are expected to increase 10 times. The wide variety of processing under this category prevents discussion of typical waste products. In fact, one characteristic will be the constantly changing quality of waste waters. Some of the most crucial waste control problems may be expected from this industry because of the complex nature of waste products and the difficulty of research in waste disposal keeping abreast of new developments. The expansion of the chemical industry may be expected in all parts of the Nation, with special emphasis on the South and Southwest.

Petroleum refining will increase fourfold. It is believed that most of this expansion will take place within presently established plant locations with some expansion in the North Central States of North and South Dakota, Nebraska, Wyoming, and Kansas. Petroleum waste products include brines, lost oil, sludges, processing chemicals, and cooling waters. Greater control of such wastes are already planned. There are plans to use air cooling exclusively instead of water cooling with considerable savings in plant construction as well as maintenance and operation. Water resources conservation will also gain.

Electric power generation is expected to increase about 10 times. Most of this will be steam generating plants. Cooling-water problems from these generating plants were discussed earlier. However, hydroelectric installations usually require impoundments to store water for power generation. These impoundments alter stream characteristics such that in some instances they create conditions equivalent to introduced pollution. Stream flows downstream may also undergo alterations that are detrimental. Hydroelectric power is used mainly to meet periodic peak demands. This use requires greater water discharges at times of peak demand, with less water, or no water, flowing through the turbines at other times. The resulting flows, approaching zero over weekends in some instances, reduce available water for downstream uses. Reregulating reservoirs are required to counteract these irregular releases, further illustrating the need for overall water resource use planning.

Effects of industrial pollutants.—The effects of the organic oxygen-demanding substances in industrial wastes are much the same as those from municipal sewage. However, little data are yet available to permit a quantitative evaluation of these wastes. Estimates of average daily population equivalents for some of the more important industries producing these wastes were prepared in 1953 by William Rudolfs in connection with a study published by the American Chemical Society. These are shown in the following table. They will serve to give an idea of the magnitude of this type of industrial wastes. The following quotation from Rudolfs' monograph from which this table was taken is indicative, however, of the need for more comprehensive basic information on this subject. "No reliable statistics are available to estimate the reduction of industrial pollutional matter by treatment, but on the assumption that half of the pollutional material is removed, it is evident that the industrial waste treatment problem is of greater magnitude than the domestic sewage treatment problem."

Population equivalents of groups of industrial wastes in the United States [1]

[Average daily population equivalents of the more important oxygen-demanding wastes produced by industry groups listed below]

[*In millions*]

Industry:	
Paper, pulp, and board	43.6
Fermentation (alcohol, beer, wine, yeast, and antibiotics	29.7
Packing and slaughterhouse	12.5
Textile, dyeing	9.9
Canning and freezing	9.3
Beet sugar	17.0
Petroleum refining	3.5
Miscellaneous (synthetic rubber, tannery, soap, and fat processing)	4.7
Total	134.4

[1] Rudolfs, William, "Industrial Wastes—Their Disposal and Treatment," ACS Monograph Series, No. 118, p. 3 (1953). Quote from book p. 4.

Characteristics of industrial wastes other than the oxygen demanders are of equal to or greater importance than the oxygen demanders when considering the many purposes of water use. Toxicity of components of some of these wastes, for instance, cannot be suitably expressed in comparison with domestic sewage. Each toxic substance must be evaluated separately as a possible pollutant. Bioassay techniques have been utilized for determining toxic characteristics under various conditions, using survival of fish and aquatic life as an index to the poisonous nature of certain wastes. Various other pollutional characteristics of industrial wastes that require attention and need to be reported on individually rather than by comparison with sewage, include dissolved substances, oil and grease, acidity or alkalinity, pH, odor, color, taste, and temperature. Mineral as well as organic substances are important. Salinity, for instance, has to be given careful consideration in relation to downstream water uses. Radioactivity is increasingly becoming a vital factor as industrial application of nuclear energy expands in this country.

These non-oxygen-demanding industrial pollutants have an adverse effect upon water usage. Because of their persistence, they reach water supply intakes and cause tastes and odors directly or through secondary products associated with chlorination. Health officials are becoming increasingly concerned over the possible long-term toxic effects of these wastes. If toxic, they can have an adverse effect on public health, although the results may be insidious and difficult to detect. Inert material of a particulate nature may settle out and coat streams' beds, leading to a barren stream. They are of economic significance also, since some cause increased hardness and require additional treatment prior to use. It might also be noted that certain other industrial wastes, such as lint and sawdust, which are very slow oxygen reactors, sometimes also act like sediments and smother streambeds.

Ingredients of industrial wastes which cause tastes and odors include such substances as phenols, mercaptans, and ammines, which may seriously interfere with use of the water for drinking or food processing. Where it has not rendered water totally unfit for use, such pollution has frequently necessitated difficult and costly purification procedures. Corrosive substances, such as acids and alkalis, or toxic contents of wastes, like cyanides, copper, chromium, zinc, and phenols, have been found destructive to livestock, to fish and to other aquatic life, both animal and vegetable. Interference with natural processes of stream purification may markedly influence quality of water available to downstream intakes. Corrosive characteristics increase costs in industrial use, and in maintenance of structures for navigation and power.

Minerals such as calcium and magnesium can create excessive hardness in water, interfering with its usefulness in some manufacturing processes. Brines or wastes with high salt content may prove objectionable if the chloride content exceeds acceptable limits for municipal and industrial water supply, fresh water fish, and irrigation. The concentration of many of these industrial chemicals is cumulative with successive uses and discharges as the water moves downstream. Common standards may therefore be required in particular rivers which would have the effect of limiting the strength and volume of the discharges from all users on the river to levels such that at no point on the river would the accumulated concentration of these substances rise above acceptable limits.

Magnitude of the problem—How extensive is the problem of abating this anticipated pollution of water by industrial wastes? None of the various estimates which have been made are complete or satisfactory because of the lack of adequate basic data. Some clue to the situation in this country is indicated from information obtained by the Public Health Service.

There are more than 280,000 manufacturing establishments in the United States. Of these, more than 150,000 report significant amounts of water used and hence produce liquid wastes with potential problems of reducing such wastes. Of the total number of manufacturing establishments all but about 25,000 discharge their liquid wastes to municipal sewer systems. Estimates of the proportion of the total municipal sewage loads to be attributed to these associated industries appear elsewhere in this report. Although only rough estimates are available, it is felt that the pollution discharging direct to watercourses from these remaining 25,000 plants is far more important both in terms of total volume and strength than are the wastes from those industries discharging through municipal systems. This offers a challenging

problem, particularly as needs for clean water increase.

GROUND WATER—A SPECIAL PROBLEM OF WATER POLLUTION

Because of the nature of ground water occurrence and flow, the control of pollution in ground water presents a special problem.

Withdrawals, of ground water in the United States averaged about 41 billion gallons a day, or 16 percent of the total estimated water used for all purposes. While over half of this amount is used for irrigation, municipalities obtain about 25 percent of their water from wells and springs. Industry uses ground water to satisfy about 10 percent of its needs, and rural users of water, not including irrigation, depend on wells and springs for 95 percent of their supply. These data are summarized in the table below.

Estimated U.S. ground water use, 1954

[In billions of gallons per day average]

Purpose	All sources	Ground water	Percent
Municipal	17.00	4.18	25
Industrial	60.00	6.13	10
Irrigation [1]	119.84	24.75	13
Rural [2]	5.40	5.16	95
Other	59.80	1.02	2
Total use	262.04	41.24	16

[1] Total take, including delivery losses but not reservoir evaporation.
[2] Nonfarm domestic, farm domestic, and farm stock wells.

By the year 2000, the scramble for water could well reach startling proportions and underground reservoirs, which are only now beginning to feel the pinch from the mining of their resources and from pollution, could be exploited and misused to the point of eventual destruction. Pollution from both surface sources and underground injection could render useless large volumes of needed ground water, unless precautions are taken against this eventuality.

Ground water pollution factors.—There is a profound lack of knowledge of many aspects of ground water. This is particularly true of ground water pollution. Some data exist on the movement and volume of ground water and related problems of bacterial pollution. However, little is known of the actual effects of chemical, mineral, and radioactive substances and the more exotic new contaminants on the aquifers and the soil and rock within which they occur. There are indications, theories, and lines of approach but, since these involve mainly new concepts, there is little truly substantiated data. Many of the problems and their possible ramifications are just now being realized. There is, however, one fact which is known and cannot be emphasized too strongly. That is the "wide" and "long time" effects of ground water pollution.

Pollution of ground water by long-time contaminants is far more serious than similar contamination of relatively transient surface waters. When streams become polluted, the situation can usually be remedied by treatment or by removing the sources of pollution. In any case, the polluted waters move rapidly downstream and pass out of the picture in a relatively short time. Underground waters, on the other hand, are out of reach and move perhaps only a few feet a day. Years or decades may pass before pollution is detected, but once it has occurred, recovery may require an equal number of years The affected aquifer may never regain its original quality.

Pollution of any water may lead to numerous public health problems. This is particularly true of ground water since such a relatively large proportion (80 percent) is used without treatment. Health problems may include not only the more publicized infectious diseases, but also the noninfectious and physiological aspects of public health.

It is contended that the infectious pollution of underground water supplies is not a serious problem. It is true that bacterial pollutants may be more easily destroyed underground than are the dissolved contaminants, since the coliform bacteria used as indicators of infectious pollution usually travel only a short distance through soil before being filtered out and dispersed. However, while these factors may reduce the danger of bacterial pollution, they in no way eliminate it. In one eastern statewide survey of over 2,000 wells, only 43 percent of the dug wells and 63 percent of the drilled wells were coliform free to the degree required by potability standards.

In addition to the bacterial pollutants, some other substances which find their way into ground waters, such as chromium, are known to be toxic. Other substances of a persistent and stable nature, for which information on health aspects is as yet inadequate, give indications of being deleterious to public health. One of the best

examples of these latter substances is alkyl benzene sulfonate (ABS), whose main sources are household detergents and industrial cleansers. Although this is only one of many stable organic pollutants, information on ground water pollution by this material indicates the problem to be of considerable magnitude.

The effects of these and other less known wastes on public health are uncertain. The effects of radioactive materials in the ground water are now under study. Questions such as the significance of detergents and other dissolved organics as agents which induce the transportation of bacteria, viruses, or other pollutants greater distances than normal, or the effects of increased phosphates on numbers and survival of bacteria in ground water, still need answers. Until the answers to these and many other questions are found, it is prudent that we view with concern the presence of any of these substances in ground water.

Of all the ground water pollution problems, perhaps the most publicized other than bacterial pollution is salt water encroachment. This term includes all cases of pollution of fresh underground water by salt and thus covers brines and salt formations as well as sea water intrusion. Many States have had problems of salt water encroachment of one sort or another. Problems due to brines or salt deposits are most commonly due to poor well location or lack of care in encasing wells. Sea water intrusion is caused mainly by excessive pumping of the ground water which allows sea water to flow in to the ground water reservoirs. On the California coast, 19 out of 79 ground water basins were reported in 1950 to be more or less seriously affected by sea water intrusion. Ground water supplies in the coastal parts of Maryland, New Jersey, and Long Island have been similarly affected.

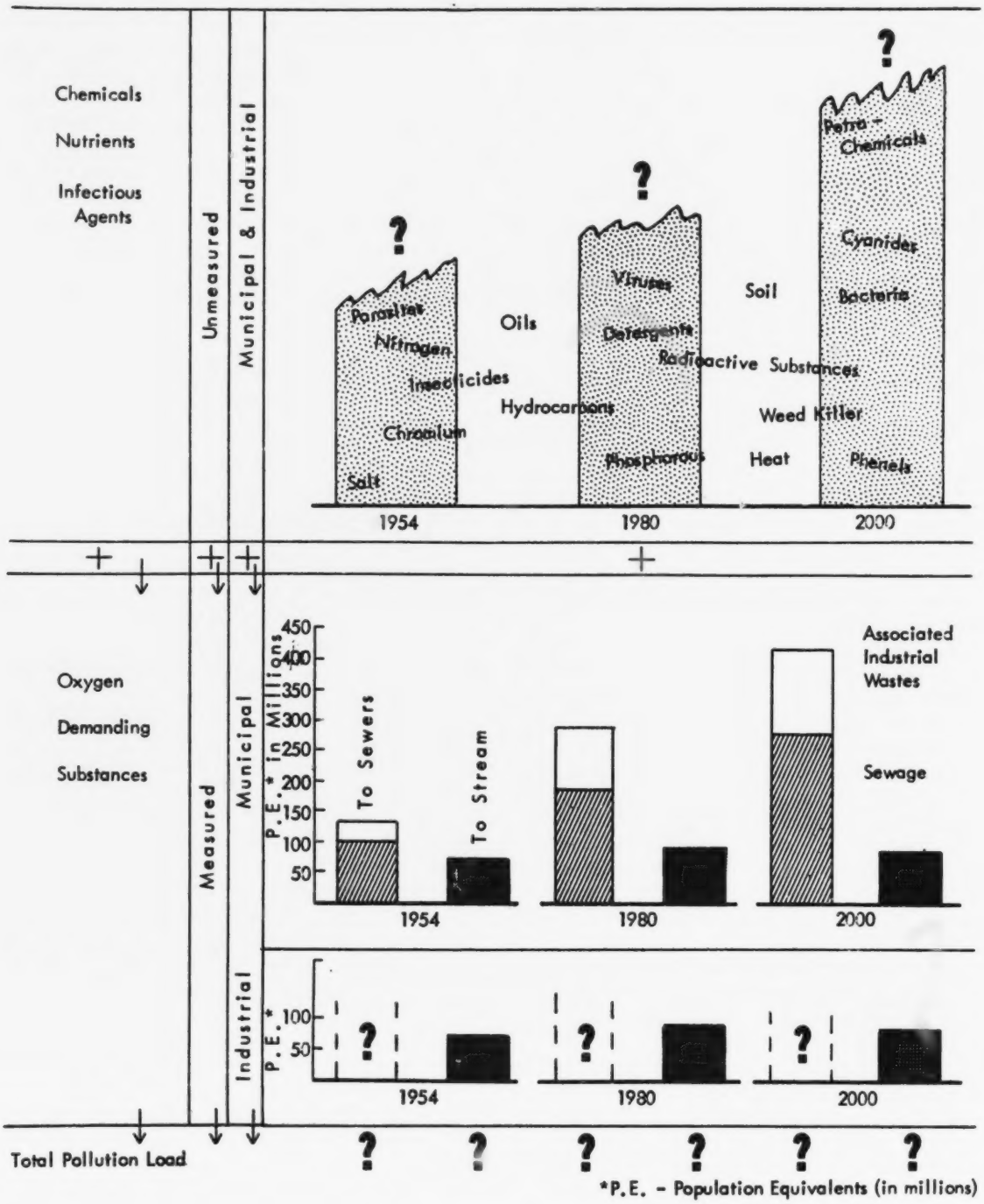
Mechanics of ground water pollution.—In addition to intrusion, ground water reservoirs can become polluted in other ways. Increasing use of irrigation, spray disposal of sewage effluents, leachings from refuse dumps, and natural impurities dissolved through water movement are some of the more obvious. A case not so obvious, but one involving a much greater potential hazard should it become accepted practice, is the disposal of wastes by the so-called deep well method. This consists of drilling a hole to a suitable stratum and pouring or pumping into it any extremely noxious wastes too difficult or troublesome for surface disposal. The extreme danger to useful aquifers pierced on the way down and made subject to eventual contamination; the possibility that the wastes may appear on the surface although probably at a great distance away and many decades later; and the chance that the Nation might eventually need to use the water or deep resources being contaminated are all factors which generally receive too little attention.

A significant illustrative example of possible ground water pollution is the situation recently discovered in the Rocky Mountain Arsenal area in Colorado. A portion of this establishment was leased in 1946 to a private corporation for the manufacture of a variety of chemical compounds including insecticides, pesticides, and herbicides. Waste products from arsenal and lessee operations, stored in ponds, were reported to have contained a wide variety of both organic and inorganic chemicals, acids, and alkalis. In 1951, destruction of vegetation in the vicinity which was irrigated from shallow ground waters occurred. Seepage from the storage ponds is suspected as the source of contamination, and the water supply of nearby communities appears to be threatened. Intensive studies are now under way by Public Health Service and others. If the ground waters of the area have in fact been contaminated by the storage ponds, it may take years before the pollution is dissipated.

Importance of recognizing ground water pollution problems.—With the anticipated population expansion, the demand for ground water should double by 1980 and, by the year 2000, perhaps reach the safe yield of a majority of the Nation's individual ground water basins. In areas where evaporation losses are great and water extremely scarce, it is reasonable to expect the creation of artificial ground water reservoirs in place of surface reservoirs. With the demand for ground water approaching the even generous supply available, the preciousness of quality is becoming apparent. The precaution with which such cities as Pasadena, Calif., or Miami, Fla., zealously guard their ground water supplies against pollution and overwithdrawal amply illustrate this point.

Probably the most significant characteristic of ground water degradation is the fact that it is usually a cumulative, insidious process. Like cancer, it can best be treated in its incipient stages.

PROJECTED TOTAL WATER POLLUTION LOAD
TREATED VS. UNTREATED



*P.E. - Population Equivalents (in millions)

Once well established, it is very difficult to correct. It is particularly important, therefore, that ground water quality be maintained at a high level and not be allowed to deteriorate through pollution of any sort. In many cases, maintenance of water quality becomes the limiting consideration in ground water basin operation.

THE FUTURE OF WATER POLLUTION

The foregoing data and discussions indicate that water pollution is extensive throughout the United States. Projections of population growth and industrial activity indicate that this pollution will become a great deal worse in the next four decades, unless widespread measures, existing or to be developed, are adopted for its abatement or prevention.

Methods have been developed for treating the traditional oxygen demanding wastes found in sewage and many industrial discharges, which are able, at reasonable costs, to remove from these discharges up to about 90 percent of these substances, although much additional knowledge and further improvement in processing are required if these results are to be bettered. With respect to other types of pollution, however, we are becoming increasingly aware of an array of substances, old and new, which have entered the picture in recent years. These now require evaluation together with development of economical processes for their control. Most of these substances are either relatively stable residual compounds left in water after the oxygen demanders have been satisfied, or are contributed directly by industry through their waste discharges or indirectly through the use of their products. The effects of these substances upon human beings or other water users or uses is as yet little understood. Quantity or point of origin of many of them are unknown. Water pollution thus is fast becoming more a chemical and physical rather than a biological problem, requiring new concepts of conservation of materials at source, maximum treatment of wastes and better understanding of toxic effects.

The amount of water available for all uses in the United States is limited. As the pressures upon this limited supply increase with the growth of the Nation, it will be necessary to manage this resource in such a way as to maximize its use for all possible purposes. For this purpose, not only is it necessary to learn a great deal more about how to remove from water the numerous substances which pollute it, but to develop techniques, processes, and controls for keeping them out of water in the first place. It will also be necessary to devise political and other organizational and managerial procedures and arrangement for regulating and apportioning our water resources among the many purposes which they serve. These are the problems of water quality management. They will be dealt with in part III of this report.

Appended are selected examples of specific water pollution situations, illustrative of some of the problems discussed in the foregoing pages.

SUMMARY

1. There is justifiable concern among planners that the large increase and shift of the total U.S. population in the next 20 to 40 years will result in a widespread and serious increase in water pollution problems. It is estimated that, at medium rates of growth, the total population will reach about 244 millions by 1980 and about 330 millions by 2000.

2. Corresponding residual sewage loads reaching streams from municipal sewerage systems and treatment plants, including industrial wastes discharged to municipal systems, for the years 1954, 1980, and 2000 are estimated to be equivalent to populations of 75, 87, and 84 million, respectively. Oxygen-demanding industrial wastes discharged directly to the streams raise these totals to 150, 174, and 168 million population equivalents, respectively.

3. Flows from municipal sources are conservatively estimated at 16.7 billion gallons for 1954, 28.6 billion gallons for 1980, and 42.5 billion gallons for the year 2000.

4. Data covering waste discharges from municipal sources are essentially complete, while data on industrial waste characteristics and volumes are notably lacking. The overall industrial production index is conservatively estimated to increase from 134 in 1954 to 767 by the year 2000.

5. The period following World War II has introduced many new types of wastes into our environment, resulting from our technological advances. The pollutants can be very persistent, and little is known of their behavior in our environment. Synthetic organic chemicals, radio-

active substances and newly identified viruses and other disease-producing microorganisms are the materials of principal concern.

6. The nuclear energy industry could experience a relatively large expansion in the next 20 to 50 years, especially for power production purposes. By 1964 we can expect a production level of 10,000 megawatts, and this is expected to grow to 650,000 megawatts by 2000. If this growth occurs, about 1 million gallons of high and intermediate level wastes will have to be stored by 1964, and by 2000 this is expected to accumulate to 300 million gallons. Other uses of nuclear energy could raise these amounts substantially.

7. Our streams are being intermittently polluted by soil and sediments resulting from land surface runoff. Excessive sediment load in streams may continue well past the year 2000. While the amount of these sediments reaching the streams may be reduced, much needs to be done in developing control measures for this type of pollution.

8. Pollution of ground waters has only recently been recognized as a significant problem. As of 1954, 25 percent of our population was being served by ground water supplies. About 40 billion gallons per day, or some 16 percent of the total used for municipal, rural, industrial, and irrigation purposes was being drawn from ground sources. This is expected to double by 1980.

9. Proper orientation of overall water supply and pollution control program planning must be based on adequate information about current conditions. Basic data collection and evaluation must be continued and expanded to enable responsible agencies to carry out comprehensive programs for water quality control.

10. Extremely complex problems of waste treatment, stream sanitation, and water reuse are being created by the current and anticipated growths in populations and industries. Conventional pollution control techniques are fast becoming outmoded. The major problem areas present new challenges, and these in turn can only be met through continued and expanded research.

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APPENDIX

SELECTED EXAMPLES OF WATER POLLUTION SITUATIONS AND PROBLEMS

BOSTON, MASS.

The Boston Metropolitan District Commission sewerage system serves about 1.5 million people in 37 communities in the metropolitan area. About 305 million gallons a day of sewage is discharged to Boston Harbor, 124 million gallons daily through the Nut Island primary sewage treatment plant (south district) and 181 million gallons daily through facilities at Deer Island (north district). A 343-million-gallon-daily primary sewage treatment plant is now under construction at Deer Island. Digested sludge from both plants will be discharged to sea on the outgoing tide from deep outfalls in the President Roads. The sludge outfall from the Nut Island plant has been in operation for about 7 years.

Construction of the 343-million-gallons-daily Deer Island plant is a major part of the MDC program to eliminate pollution in Boston Harbor. The program to provide adequate collection and treatment works includes the construction of 35 miles of trunk sewers ranging in size from 36 to 108 inches; 11 miles of deep rock tunnel 300 feet under Boston Harbor and the construction of the Nut Island and Deer Island sewage treatment plants and other works including a number of pumping stations.

The $65 million program now underway should eliminate much of the pollution from occasional overflow into nearby watercourses of sewage from overtaxed trunk sewers. The principal rivers flowing through the metropolitan area and discharging significantly polluted water to Boston Harbor are the Majestic, Charles, and Neponset Rivers. In addition, the Saugus River discharges polluted water to Lynn Harbor in the north metropolitan area. Numerous individual sewage and waste discharges from sewers and boats of all types have also contributed to the pollution picture.

CONNECTICUT RIVER AT HARTFORD

The Connecticut River, in the present stage of planning, is not considered a source for public water supplies. In accordance with the approved classification schedule of the New England Water Pollution Control Commission the stretch of the river above and below Hartford has been given a use classification of "C." This classification establishes the river as "suitable for recreational boating, irrigation of crops not used for consumption without cooking; habitat for wildlife and common food and game fishes indigenous to the region; industrial cooling and most industrial process uses."

RHODE ISLAND

If the State of Rhode Island is to hold present industry and attract new enterprise, it is essential that all establishments be assured of an adequate source of water of suitable quality and a means of disposing of its waste water that is within the economic limitations required by competitive production costs. The residential needs for adequate sewage disposal are not less important. It is of immediate interest to note that about 75 percent of the State's population, excluding military installations, lives in areas having public sewers, but that only 63 percent of that population is actually connected to sewers. These population data, based on 1956 estimates, also indicate that about 67 percent of the Providence metropolitan area was served by public sewers.

A report of the Institute of Public Administration to a "Special Commission To Appraise the Financial Operations of the State Government and the Matter of State-Local Financial Relations" in Rhode Island points out several weak features in the water-pollution law. The first of these is the provision that "No person shall be held to have violated the provisions of this chapter where the sole damage caused by him is the rendering unsuitable for drinking purposes or ice supply the waters polluted by him." Thereby a great deal of the power of the act is removed. In addition, there is a lack of provision, within the law, for the adequate control of sewerage systems and over sewage not discharged directly into the waters of the State. Thus, a city such as Warwick, with a population of 61,000, could develop without a sewerage system. The eventual public health problems may be very costly in such cases.

The waters of the State are an important water supply and recreational resource. The pollution created by municipal sewage, industrial wastes and boats, if permitted to continue, may be very damaging to these resources. In addition, large areas in Mount Hope Bay, the Providence River, Narragansett Bay, and the Pawcatuck River have been closed to the taking of shellfish, due to pollution of these areas.

There is a great need for regional development in this State.

DELAWARE RIVER

Pollution, as well as the salt water intrusion, has made the use of the Delaware River impractical as a source for water supply. The stream carries the waste of the Philadelphia and Wilmington metropolitan areas with an estimated load of 770,000 pounds of BOD per day. This is a

population equivalent of approximately 4½ million persons. Thermal pollution is currently becoming a problem in the Delaware estuary. An estimated 3½ billion gallons of water a day are used for thermal electric power in the basin, 90 percent of it in the Philadelphia-Wilmington metropolitan area. Anticipated increases in thermal powerplant construction suggest a tenfold increase of this figure by the year 2000.

NORTHEASTERN NEW JERSEY

In the northeastern portion of New Jersey, which lies within the more highly developed metropolitan area of New York City, past and present practice in pollution control has dictated long interceptor and trunk sewer systems draining upland areas directly to the tidal estuary. This process over the past years has diverted from the natural water courses significant amounts of water. This has in turn created additional problems in the water management of these waterways. With lowered amounts or flow, the tidal excursions of salt water have penetrated further upstream. Local pollution of the stream has been aggravated with lower flows. The one time use of these waters in upstream areas and diversion directly to the sea via trunk sewers may not be the most economical use of the water in this potentially water-short area. Much thought is being given to any future diversions in this manner.

PHILADELPHIA, PA

Ground water pollution

In the Philadelphia metropolitan area the heavily polluted waters of the Delaware River have been infiltrating into the major ground water reservoirs serving the area. This has progressively lowered the quality of ground water supplies, creating a need for additional treatment and development of new wells to replace polluted supplies. Induced recharging from the Delaware River supplies a substantial portion of the water drawn from the Paritan and Magothy formations. In some areas the quality of the water drawn from these aquifers approaches that of the river. It is evident that the maintenance of a good quality of water in the river is imperative if the quality of the ground water supply is to be maintained. The possibility exists in this area also for the intrusion of salt water from the ocean via Delaware Bay and River. Channel deepening in the Delaware River has increased the extent of the salt water intrusion and in addition has uncovered the deeper aquifers lying under the river bottom. The recharge of these aquifers with lower quality river and saline waters will endanger their use as a potable supply.

NORTH BRANCH, POTOMAC RIVER

Water quality in the North Branch is adversely affected by acid mine drainage from abandoned coal mines in the reaches of the river above Luke, Md. Pollution by acid mine waters is a problem not only in the North Branch Potomac River, but is common to all areas where coal is or has been mined.

Sulfuric acid is formed by the action of oxygen and water on mineral ores which are commonly found with coal deposits. Pyrite and marcasite are two of the materials commonly associated with the formation of mine acid. The basic process by which the acid is formed is not fully understood, and there are many conditions which defy a simple explanation of why apparently similar mines produce wastes of a different character and quantity.

The effect of the heavy concentrations of acid on a stream are felt in many ways. Plant and animal life in the stream is killed; consequently, the stream loses its recreational and esthetic value. The pollution assimilating capacity of the stream is greatly reduced because the acid inhibits the growth of bacteria responsible for the decomposition of organic matter. The corrosive nature of such water causes damage to boats, bridges, dams, and other equipment which come in contact with the water, and increase the cost of water treatment for municipal and industrial use.

One of the more general and far-reaching problems caused by the presence of acid in a stream is the reduced incentive for abatement of other types of pollution in the stream. Even if desirable, it is difficult to "sell" pollution abatement to municipalities discharging water into a highly acid stream.

Sanitary sewage is discharged to the North Branch from virtually all the towns and villages on the watershed, and sewage treatment facilities are practically nonexistent. Sewage loads are contributed by the Luke-Piedmont-Westernport district, Keyser, Frostburg, and Cumberland. An unusual cooperative effort toward the abatement of pollution is developing at Luke, Md. The pulp and paper company, in designing industrial waste treatment facilities and in cooperation with the communities of Luke, Westernport, and Piedmont, included provisions for treating the domestic sewage from these communities. This effort will result in greatly reduced treatment costs for the municipalities and the additional domestic sewage will aid the company in treating the industrial wastes. Cumberland recently completed and placed in operation a new primary sewage treatment plant with chlorination. The effect of the waste from the majority of the towns in the basin is insignificant in comparison with the effect of the large quantities of industrial waste present in the North Branch.

WASHINGTON, D.C., METROPOLITAN AREA

A Joint Congressional Committee on Washington Metropolitan Problems (Bible committee) has studied the complex problems of water supply and pollution control in the metropolitan area and its hearings and recommendations were published in 1958.

Administrative problems exist which impede the accomplishment of pollution abatement. There is no one agency having enforcement powers covering the entire area, making coordination of pollution abatement efforts difficult. All of the State health and water pollution control agencies, as well as the Federal agencies involved, are deeply concerned for the continued safety of the metropolitan water supply. Control of water pollution in the Potomac River and its tributaries is of prime importance in protection of the water supply. The Interstate Commission on the Potomac River Basin has recently adopted for recommendation to its member States new and more stringent water quality criteria for the Potomac River in the Washington metropolitan area. These criteria were developed pri-

marily for the protection of sanitary quality of the District water supply. Acceptance of the criteria by all States in the basin will be necessary before they will be effective tools in maintaining or improving water quality.

The problem of preventing new sources of pollution is one of coordination on an areawide basis. A recent example of the difficulties that can be encountered is the waste disposal problem at the new Dulles International Airport near Chantilly, Va. Although all parties concerned agreed eventually that the discharge of treated sewage to a stream used for public water supply (Alexandria water supply on Occoquan Creek or District of Columbia water supply on the Potomac River) was to be avoided if at all possible for public health reasons, no single agency could specify the requirements for waste disposal and follow through with enforcement. A voluntary Regional Sanitary Board, consisting of representatives of all political jurisdictions of the District of Columbia metropolitan area, has recently been formed, however, and is undertaking to finance a regional master sewerage plan study.

Assessment of the future needs for waste disposal or treatment facilities in the metropolitan area has indicated that by the year 2000 a population of 2,351,600 to 3,205,000 in the metropolitan area will contribute sewage to the Potomac River. An extremely high degree of treatment must be provided for all discharges if the assimilative capacity of the river is not to be exceeded. Highly treated effluents have as constituents nitrogen and phosphorus in a form available for plant food. The addition of these minerals to the river may stimulate further the growth of algae, which may in turn produce undesirable conditions.

Effective pollution abatement in the metropolitan area must include the elimination of intermittent discharges of large amounts of raw sanitary sewage through sewers carrying a combination of sewage and storm water. Discharges of this nature should be minimized to the greatest extent possible. This is a problem of great magnitude involving large sums of money and a long period of time for its solution. The cost of changing all areas of the District of Columbia to the separate system has been estimated to be $300 million.

POTOMAC RIVER TIDAL ESTUARY

The tidal estuary of the Potomac River behaves as a lake or reservoir. In effect, the sewage from the Washington metropolitan area is discharged to a sluggish pond. The tide and wind cause the water to move up and downstream and to circle between its banks. It has been estimated that it takes 40 days for the water to move the 15 miles from Three Sisters Islands to Fort Washington during the summer months. Thus the sewage discharged is not carried immediately downstream but remains in the metropolitan area for many days. The estuary is used extensively for navigation, pleasure cruising, and sailing. Other and more extensive recreational uses could be made of the estuary for swimming and fishing if water quality were satisfactory.

A plan for conveying treated sewage from the Washington metropolitan area to Chesapeake Bay has been proposed as a means of solving the pollution problems in the tidal estuary. This would require in the year 2000 that 630 million gallons of sewage per day would be pumped through a pipeline leading from the Blue Plains sewage treatment plant to Chesapeake Bay, a distance of nearly 30 miles. Such a project is estimated to cost $55 million at 1957 prices. A comprehensive study of the probable effects of such a discharge on marine life in Chesapeake Bay would be necessary before a decision to proceed with construction could be made.

Natural pollution in the form of silt also has an adverse effect on the tidal estuary. It is estimated that the Potomac River carries 60 million cubic feet of silt each year, most of it deposited in the metropolitan area. The annual silt load could completely fill the tidal Potomac from Chain Bridge to Fort Foote in 50 years. Dredging operations have helped combat this problem, but spoil areas for the dredged silt are becoming difficult to obtain. Land-treatment measures throughout the basin will be necessary to substantially reduce the silt load carried by the river.

HAMPTON ROADS, VA.

The multimillion-dollar shellfish industry plays an important role in the economic structure of the Hampton Roads area as well as the State of Virginia. The industry, however, requires waters of high bacterial quality to insure a contamination-free product. The expanding population of the Hampton Roads area has created problems of sewage contamination of growing areas. Over 38,000 acres in the Hampton Roads area are restricted for the taking of shellfish.

Although four sewage treatment plants in the area provide a degree of protection for the shellfish growing areas, the discharge of inadequately treated sewage occurs because of overflow or breakdowns.

The bacterial quality of the shellfish growing areas is also endangered by raw sewage discharges from the large number of naval vessels which dock in the Hampton Roads area. The development of an effective economical method for abatement of this shipborne pollution would be of great value in this and other areas.

Another aspect of shipborne pollution which may affect shellfish growing areas is the construction and operation of nuclear-powered ships. The future development of the Hampton Roads area will probably see the Norfolk Naval Base area in use as base of operations for nuclear vessles as well as the routine use of the Newport News shipbuilding area as one of the major repair and/or refueling yards for nuclear-powered vessels. It is apparent that until more information regarding permissible radiation levels in shellfish is known, the Hampton Roads area presents a definite potential radioactive waste disposal probelm to the shellfish industry.

RICHMOND, VA.

The city of Richmond in the fall of 1958 placed a 70 million gallons per day primary sewage treatment plant in operation. This plant is designed to serve a 1970 population of 330,000. Approximately 50 to 60 percent of the sewage from the city of Richmond is now receiving treatment at this plant. A system of interceptors and

pumping stations is scheduled for construction that will bring approximately 95 percent of the city's sewage to the central treatment plant. The target date for completion of this construction is 1965, and the total cost of the development is estimated at about $15 million. The sewage treatment plant can be expanded to serve a metropolitan area of 440 square miles having an estimated population of 670,000 by the year 2000.

This sewage treatment plant discharges to the James River. Data on the capacity of the stream to assimilate pollution is not complete.

It seems likely that low flow regulation will be an important part of any comprehensive pollution abatement plan for the future. A number of possible improvements of the James River have been studied and discussed, including such items as flood control, local flood protection, waterpower development, and pollution abatement. Sometime in the future steps may be taken that will result in controlled minimum flows of 2,000 to 3,000 cubic feet per second and possibly as high as 4,000 cubic feet per second.

In Chesterfield County most residential units are served by septic tanks. Some small areas are served by small treatment plants, and one area is served by a pumping station discharging to the Petersburg system for treatment. Another small area is served by Richmond's sanitary system and sewage disposal plant.

Difficulty with septic tanks has resulted in increasing pressure to provide sewer service and a master plan for sewering some 13 percent of the total county area in the northeast portion has been studied. This area includes approximately 65 percent of the estimated population of the county. The problem of financing these improvements will be a complex and difficult one.

Henrico County has created 11 sanitary districts, most of which provide sewer service. Two of the sanitary districts, A and B, contain approximately two-thirds of the sewer connections in the county. Most of Sanitary District A is served by the city of Richmond's system. Negotiations are underway, however, to bring the sewage from Sanitary District B to the city system for treatment also.

It is likely that political and administration decisions will be made in the near future which will affect the pattern of waste collection and disposal in the metropolitan area. Should Chesterfield County, for example, decide to construct its own sewage treatment facilities rather than discharge to the city of Richmond's system, it is likely that only a small portion of the county will become tributary to the Richmond sewage treatment plant.

LOWER ROANOKE RIVER BASIN, N.C.

The problems of the lower Roanoke River Basin exemplify the need for not only a sufficient quantity of water but also the need for water of good quality.

There are two dams on the Roanoke River; the John H. Kerr Dam in Virginia 179 miles from the mouth of the river and the Roanoke Rapids Dam located in North Carolina 137 miles from the river mouth. The Kerr Dam, constructed in 1952, is a federally owned power and flood control structure with a reservoir capacity of 2,324,000 acre-feet. The smaller Roanoke Rapids Dam (reservoir capacity 85,000 acre-feet) is owned by a private power company and is designed for the generation of electric power. The same company has proposed the construction of Gaston Dam, which would be located between the two existing dams.

Other major users of the Roanoke include two pulp and paper industries, one approximately 2 miles below the Roanoke Rapids Dam and the other near the mouth of the river at Plymouth, N.C. The lower Roanoke River is the major spawning area for striped bass or rockfish in North Carolina. The value of this fishery for commercial and sport fishing has been estimated to exceed $1 million annually. In addition to the major users mentioned above, the Roanoke also serves as a source of water supply and as a waste disposal artery for several municipalities and smaller industries.

The Roanoke River is the largest river in North Carolina and has a great potential for municipal and industrial expansion provided that, through proper management of the water resources, a sufficient quantity of good quality water is available during critical periods. The major problem facing present and potential users of the Roanoke River is finding the means by which adequate pollution assimilating capacity, in the form of dissolved oxygen, can be maintained in the river to provide for present and future municipal and industrial expansion and, at the same time, maintain an adequate environment for striped bass spawning. At the present time one of the large industries on the lower Roanoke is contemplating a multimillion-dollar expansion, contingent upon the availability of adequate pollution assimilating capacity.

The owners of Kerr and Roanoke Rapids Dams add no sewage, industrial wastes, or other wastes to the Roanoke River; and the water is merely impounded and discharged through low level turbine intakes. Under a strict interpretation of State law, the owners cannot be considered polluters, yet, because of thermal stratification, the water discharged from the impoundments is low in dissolved oxygen content during certain periods of the year and adversely affects downstream uses.

The steering committee for Roanoke River studies was formed in 1955 to study the many pertinent aspects of the river problem. One of the biggest problems which confronted the committee was finding a method by which good quality water could be extracted from a thermally stratified reservoir. The first recommendation of the steering committee was for higher minimum flows during the summer months and during the striped bass spawning season. The private and Federal operators of Roanoke Rapids and Kerr Dams cooperated in the experiment and studies indicated that the increased flows helped to increase the assimilating capacity of the river by increasing the volume of water, but that the low dissolved oxygen condition remained. After further studies by the steering committee, it was recommended that a submerged weir be constructed in the Roanoke Rapids Reservoir immediately upstream from the turbine intakes for the purpose of skimming off water with a high dissolved oxygen content. The owner again cooperated by constructing a weir with the crest 25 feet beneath the water surface. Studies of the performance of the weir indicated that it improved the quality

of the water discharged from the dam and that the design of future dams on the Roanoke should include a submerged weir.

The owner of the dam presently has an application before the Federal Power Commission for the construction of Gaston Dam. This dam, to be located between the existing Roanoke Rapids and Kerr Dams, would inundate all of the free-flowing water in this reach of the river and thus destroy an important reaeration zone. Based on the performance of the submerged weir at the Roanoke Rapids Dam, the owner has agreed to construct a similar weir at Gaston Dam with the crest, in this case 15 feet beneath the water surface. It is not known, however, whether or not the proposed weir at Gaston Dam will insure the discharge of water with an adequate dissolved oxygen content from Roanoke Rapids Dam.

The discharge of water low in dissolved oxygen content is a problem which is not restricted to the Roanoke River but is inherent in all deep reservoirs with low-level turbine intakes. The ultimate answer to this problem will be provided only in the light of extensive research.

OHIO RIVER BASIN

The following quotes taken from the "11th Annual Summary (1959) of the Ohio River Valley Water Sanitation" are indicative of progress being made in this eight-State area.

"Purification plants serving 95 percent of the population (on the main stem of the Ohio River) are now operating or nearing completion. Less than 1 percent of the population was serviced 11 years ago."

"Action within the borders of each of the signatory States has resulted in this record: 8,400,000 people—which represents 82 percent of the sewered population in the entire drainage district of the Ohio Valley—now have sewage treatment plants operating or under construction."

"Of the 1,442 industrial plants that discharge effluents directly into streams, 80 percent are reported by signatory States as complying at least with minimum requirements established by the Commission. And 916 of the plants included in this group are rated as having adequate control facilities."

"Whatever has been accomplished, however, provides no basis for complacency. Conditions in the upper Ohio, and on some of the tributaries are still far from satisfactory. Oil pollution, for example, as well as the discharge of certain industrial effluents hardly can be said to be under adequate control. Neither has there been a demonstrable reduction in acid discharges from coal-mining operations. And a few communities have been notably laggard in meeting their obligations."

The accomplishments listed above show substantial progress, but it is reported that a number of cities using Ohio River water as a source of municipal supply are still beset with serious and recurring taste and odor problems, and that there are other problems, such as buildup of chloride concentrations and difficulties with respect to fish in the upper reaches of the river.

MAHONING RIVER

The steel mills and coke ovens on the Mahoning River raise the temperature of the water to unusually high values. The peak industrial use is several times the low flow of the river. Withdrawals reach 2,000 cubic feet per second while the regulated, minimum monthly average flow during July (1943–52) was 479 cubic feet per second. In the "West Branch Reservoirs, Ohio—Report on Low Flow Regulation Benefits; PHS October 1956" the calculated river water temperatures at various flows were as follows:

Cubic feet per second	°F.
175	128. 0
300	116. 6
400	109. 4
500	104. 0

The "Report of Water Pollution Study—Mahoning River Basin, 1954," Ohio Department of Health, gives the following quantities of significant industrial wastes discharge to the waters of the basin.

Population equivalent (BOD)		107, 920
Oxygen demand from ferrous iron	pounds	17, 240
Acid as ($CaCO_3$)	do	347, 600
Phenols	do	2, 997
Oil and grease	do	37, 680
Total iron	do	339, 060
Total solids	do	1, 383, 320

The solution to the pollution problem in the Mahoning River Basin appears to be controlled low flow by release from storage reservoirs for temperature control plus adequate treatment of the other pollutants. Industrial growth in the area has been limited, in the past, by lack of adequate water of satisfactory quality. The construction of the West Branch Reservoir will alleviate the condition somewhat, but a large industrial expansion seems unlikely unless more water can be made available.

NASHVILLE, TENN.

There are major problems here in the treatment of both industrial and municipal wastes. The present treatment plant removes but 50 percent, at most, of the BOD; treats but half of the sewage of the entire Nashville metropolitan and urban areas; and the plant now is overloaded. A plant of adequate size to treat the present sewage load probably will need to be doubled in size by 1980, and doubled again by the year 2000.

It will probably be necessary to establish a sanitary (city-county) district in order to solve the financial problems attendant upon provision of adequate waste collection and treatment facilities at a single location. The major problem is financial.

The present municipal and industrial waste load in the Nashville metropolitan and urban areas is probably 600,000. There is pollution of the Cumberland River below Nashville.

A difficult industrial waste problem for the State water pollution control commission results from a lack of sufficient knowledge of the nature and treatment required for some types of industrial wastes.

LAKE MICHIGAN, SOUTHERN TIP

The heavy concentration of industry and population in the area at the south end of Lake Michigan presents a special problem in relation to waste disposal and use of the water for municipal and industrial water supply. Wastes which are discharged to the Calumet and Grand Calumet Rivers, Indiana Harbor Canal, Gary Harbor Canal, and Burns Ditch, can and do reach Lake Michigan. In addition, wastes are discharged directly to the lake from industries on its shore. Water supplies taken from the lake are affected to varying degrees depending upon the location of the intake, the lake currents, water temperature, wind, and many other factors. Our present knowledge does not permit a determination of what wastes affect which water supplies and the extent of these effects. A survey is needed to arrive at a possible solution. This situation is similar in many respects to those encountered in tidal estuaries along the sea coasts.

CHICAGO, ILL.

The sewage entering the Chicago sanitary and ship canal from the Chicago metropolitan area has an estimated population equivalent ranging from 800,000 to 1 million. Actual figures cannot be secured because of the lack of information on amount of storm water overflow, bypassing of treatment plants, adequancy of the collection system, etc. Conditions will probably continue to deteriorate unless extraordinary measures are taken. If Chicago continues to grow as it has during the past 50 years, the waste discharge will probably double to about 2 million population equivalents.

Pollution of bathing beaches on the Great Lakes is a recurring problem. Several beaches are closed every year because of bacterial pollution. The late summer of 1959 found one or more beaches closed at almost every major city on the Great Lakes except Chicago. It was unofficially reported that the only thing that saved Chicago from closing some of its beaches was the fact that the season ended before the bacteria counts, which were climbing steadily, reached the maximum allowable concentration.

Heat pollution is also quite extensive in the Metropolitan Chicago waterways. The Commonwealth Edison Co. has eight steam plants using water on a once-through basis. The following table gives the water needs of these plants, the amount of water available for these needs, and the waterway from which water is taken.

[In cubic feet per second]

Plant	Plant cooling requirement	Canal or river flow available
Chicago River: Northwest plant	665	710
Chicago sanitary and ship canal:		
Fisk plant	1,460	1,575
Crawford plant	1,525	1,575
Redgeland plant	1,350	2,900
Calumet River: Calumet plant	1,120	275
Des Plaines River:		
Will County plant	1,200	3,400
Joliet plant	1,060	3,550
Illinois River: Dresden plant	380	4,000

The amount of temperature rise is not known but is probably several degrees. This increased heat reduces the oxygen in the water which is needed by the Chicago Sanitary District to alleviate the pollution caused by its waste. Part of the solution might be the installation of cooling towers so only makeup water would be needed from the waterways. A long-term solution would be location of future powerplants on Lake Michigan where ample cooling water is available.

DETROIT, MICH.

The rapid suburban development resulted in a conglomerate maze of sewer systems which need to be tied together into a workable system. Many of the sewers are of the combined type which overflow into adjacent waterways during rains, thereby polluting the receiving waters. Considerable progress has been made toward the solution of this problem under the guidance of the Michigan Water Resources Commission and it appears to be well on the way toward final solution. A higher degree of sewage treatment will probably be required before 2000 to protect the downstream municipal water supplies.

Supplemental irrigation is increasing in the Michigan area. There is a growing concern that riverflows may be depleted to such an extent that little or no flow will be available for diluting sewage treatment plant effluents. There are two areas in Michigan where irrigation is beginning to have a damaging effect on water pollution control. The Grand River and its tributaries above Grand Rapids, Mich., have been seriously depleted at times by heavy withdrawals for irrigation. These irrigation demands occurred during warm, dry periods when all the available riverflow was needed for pollution control. It resulted in a deterioration of water quality beyond that which would have occurred had the normal streamflow been available. One solution would be the reservation of the required flow for pollution control with only the excess over that flow used for supplemental irrigation. This would pose an involved legal and administrative problem. Another solution would be upstream storage of floodwater to be released for supplemental irrigation as needed. The problem is of tremendous importance to a large portion of the United States and a thorough study and solution is long overdue.

FOX RIVER

The Fox River of Wisconsin has one of the most concentrated pulp and paper industry developments in the country. The 40 miles of river, from Lake Winnebago to Green Bay, receives the wastes from 19 paper and paperboard plants, 4 de-inking pulp mills, 3 rag pulp mills, 1 kraft, 4 sulfite, 1 semichemical, and 2 groundwood pulp mills. Eight of these mills discharge their wastes through available municipal treatment facilities and the other 26 discharge wastes directly to the stream. Surveys conducted in 1956 by the Wisconsin Committee on Water

Pollution showed the following waste loadings going to the Fox River after treatment:

Suspended solids:		
Municipal [1]	pounds per day	17, 700
Industrial	do	145, 800
BOD:		
Municipal [1]	do	26, 600
Industrial	do	242, 500
Population equivalent of waste:		
Municipal [1]	do	159, 700
Industrial	do	1, 455, 100

[1] Includes waste from 8 pulp and paper mills.

This river also receives a heavy natural pollution load from Lake Winnebago, in the form of algae. There will probably be a continued increase in mill production and in the amount of industrial waste. There is, already, an oxygen deficiency at the present time during critical low flows. The solution to the problem is more adequate treatment of the waste before discharge, low flow augmentation to supply increased amount of oxygen or supplying oxygen by some other means, such as aeration of the river.

The general effects of effluents from the pulp and paper industry on receiving waters is to reduce their dissolved oxygen content, to introduce solids that may settle and create objectionable sludge deposits, to impart color and odor that may adversely affect downstream users, to exert toxic effects under special circumstances on fish and their foods, to furnish nutrients for aquatic slimes that can cause nuisances or interfere with fishing, and to contribute substances that may otherwise detrimentally affect water uses. Sulfite spent liquor continues to be a major problem. For every pound of pulp produced there is a pound plus of solids released in slightly over a gallon of the spent liquor. The liquor is, of course, diluted by wash waters, before discharge from the mill. Utilization is the most promising development for this waste. (1) Other wastes will range in strength down to 0.5 pounds or less of fiber per 1,000 gallons of whitewater wastes.

KALAMAZOO RIVER

The Kalamazoo River is a stream that receives a heavy concentration of paper mill wastes. The total load entering the river in the reach from Comstock to Otsego, Mich., averaged 555,147 population equivalents in 1956. Paper mill wastes accounted for approximately 95 percent of this load. A 1956 sampling survey showed zero dissolved oxygen conditions over a reach of 10 miles below Kalamazoo during a relatively high runoff (610 cubic feet per second). Adequate treatment of the de-inking mill waste, which was 70 percent of the total load, will most probably reduce the biological oxygen extraction rate to a point approaching the normal self-purification rate of the river. There is not enough streamflow to handle any increase in the pollution load and industrial expansion appears to be contingent upon more extensive treatment of the wastes before discharge. The Michigan Water Resources Commission has issued orders placing certain restrictions on the daily waste loads discharged to the Kalamazoo River. The solution of the problem is the reduction of the waste load either by reduction at its source or increased treatment before discharge.

MISSISSIPPI RIVER

Stable organic pollutants

The usual sanitary analyses are not effective in measuring the newer organic contaminants. A concentration method known as the carbon filter technique has been developed which permits the concentration of these substances from a large volume of water. The technique requires continuous filtration of about 5,000 gallons of water through the filter over a 10- to 14-day period, followed by extraction with two solvents, first with chloroform and then with alcohol. The resultant extracts provide useful information concerning the degree and kinds of organic matter present, as well as continuous data of value in determining pollutional trends.

The organic residue recovered from the carbon filter by the chloroform extraction is very complex. However, the residue is amenable to further separation into certain broad chemical groups, and these include ether solubles, water solubles, neutrals, weak acids, strong acids, and bases.

The alcohol extractable materials generally consist of synthetic detergents, proteins, carbohydrates, and miscellaneous natural substances. The more industrialized the pollution, the lower the ratio of alcohol to chloroform extractables. On waters of mixed industrial and domestic pollution, the chloroform and alcohol extractables may be about equal. On some streams where the industrial pollution is rather low and much natural pollution and sewage is present, the alcohol may exceed the chloroform extractables by a factor of as much as 4 to 6.

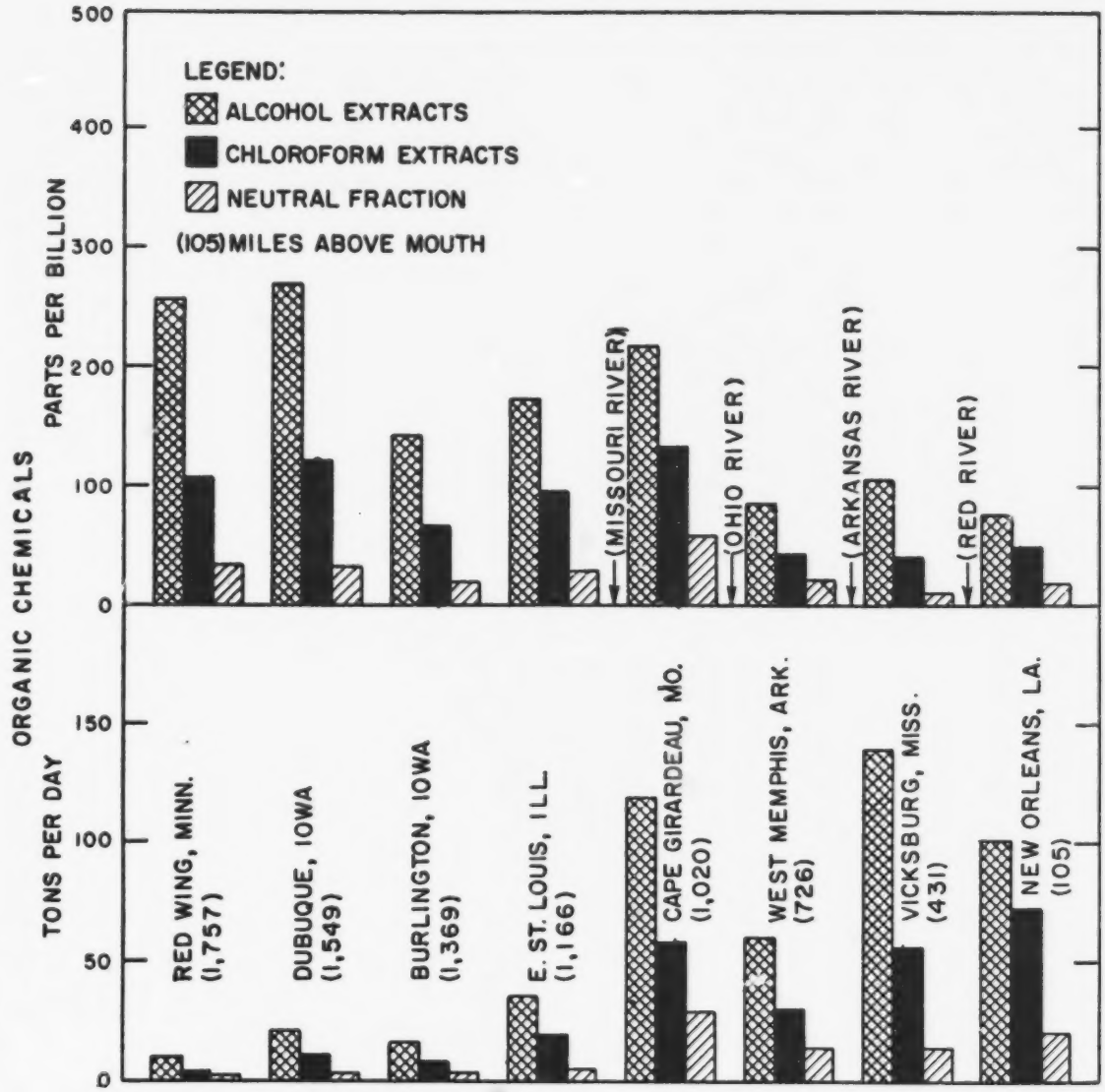
The alcohol extract is usually water soluble but not ether soluble. Very little further chemical separation has been applied thus far on this material. A recent series of tests, however, revealed that as much as 12 percent of the alcohol extracts consists of synthetic detergents.

The data collected by the National Water Quality Network for the period October 1, 1957, to September 30, 1958, while limited to a single year of coverage, shows some interesting relationships with respect to the presence of these pollutants in the Mississippi River. The results are presented in figures 1 and 2.

Figure 1 presents the average concentrations and stream loadings for the alcohol extractables, the chloroform extractables, and the neutral fraction for each of the Mississippi River stations. The upper section of the river shows the higher concentrations of alcohol extracts, or "natural" organics. At Red Wing and Dubuque the concentrations are over 250 p.p.b. At Burlington there is a sharp decrease to about 140 p.p.b., rising again to about 215 p.p.b. at Cape Girardeau. At West Memphis, the levels have decreased to 85 p.p.b. There is a nominal increase at Vicksburg, with final concentrations at New Orleans averaging about 75 p.p.b. There are apparent effects from both the Missouri and Arkansas Rivers, but there appears to be little influence from the Ohio River.

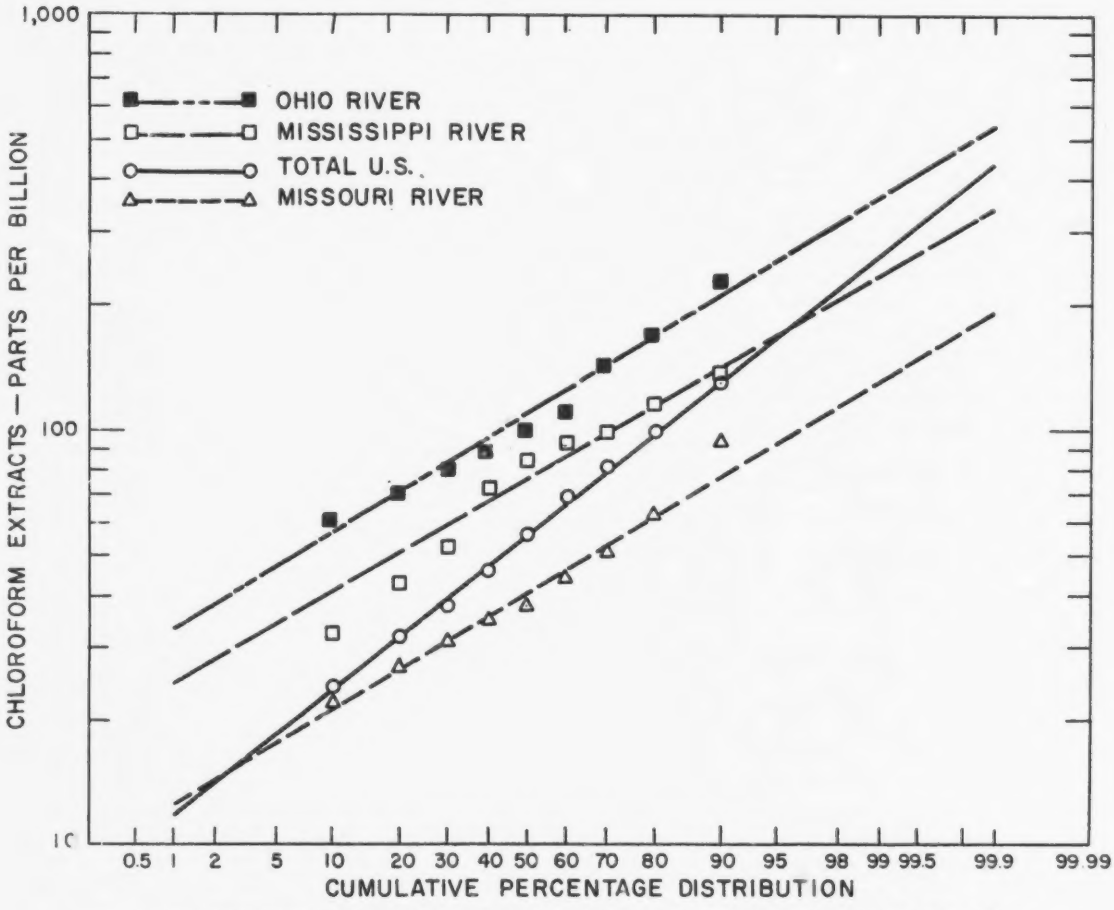
The trends shown by the concentrations of chloroform extractables and their neutral fractions are similar to each

FIGURE 1



AVERAGE CONCENTRATIONS AND STREAM LOADINGS OF ORGANIC CHEMICALS FOR THE MISSISSIPPI RIVER

FIGURE 2



FREQUENCY DISTRIBUTION OF CHLOROFORM EXTRACTABLE MATERIALS, MISSISSIPPI RIVER BASIN AND TOTAL U.S.

other and to the alcohol extractables. For the total chloroform or man-made materials the concentrations are somewhat over 100 p.p.b. at Red Wing and Dubuque. At Burlington the results show 65 p.p.b., with an increase to over 130 p.p.b. occurring between there and Cape Girardeau. A combination of flow time and dilution reduce the concentration to about 40 p.p.b. at West Memphis, and this condition remains through New Orleans. The neutral fractions follow a similar trend, reaching a maximum of about 60 p.p.b. at Cape Girardeau, but falling to less than 20 p.p.b. in the lower reach. The Missouri River is the only one of the tributaries whose influence is reflected on the main stem.

The total loadings, based on the streamflows and concentrations, show a different pattern from that of the concentrations alone. For "natural" organics, there is an increase from 10 to 35 tons per day between Red Wing and East St. Louis. There is a sharp increase at Cape Girardeau to over 120 tons per day, reflecting the entrance of the Missouri River and the contribution of the St. Louis area. The highest loading of about 140 tons per day occurs at Vicksburg, though this station does not show the highest concentration. At New Orleans the stream is carrying about 100 tons per day of these materials. The data clearly show that the area below the Missouri River carries the greater loads.

The chloroform or "manmade" organics are also lowest in the upper Mississippi River. The loadings vary from under 5 to about 20 tons per day between Red Wing and East St. Louis. At Cape Girardeau the load is just under 60 tons per day. This is reduced to about 30 at West Memphis, hence increasing to about 75 tons per day at New Orleans. The highest loadings occur at New Orleans, and this again is not evident from the data on concentrations.

The load of neutral fractions follows the same trend as the total chloroform materials. The stream carries less than 5 tons per day between Red Wing and East St. Louis. The highest loading, about 30 tons per day, occurs at Cape Girardeau. This is reduced somewhat in traveling downstream, with 20 tons per day passing New Orleans.

Figure 2 shows the frequency distribution of concentration levels for the Mississippi, Missouri, and Ohio Rivers, as well as for the total United States. The distribution patterns for the three streams are similar to each other, but quite different from the pattern of the network as a whole. The Ohio River shows the highest concentrations, and the Missouri the lowest. Median concentrations were higher for the Ohio and Mississippi Rivers and lower for the Missouri River, when compared to the data for the total United States.

ST. LOUIS, MO.

Pollution of the Mississippi River in the St. Louis metropolitan area is serious. The population equivalent of wastes entering the river in this region is 5,250,000. Four million of this is industrial wastes and 1.25 million is sewage. Practically all of the wastes enter the river through sanitary district or city sewers and only a small portion of it is treated. The St. Louis area has a high potential for future growth and the waste load will probably double or triple within the next 50 years. Obviously, construction of treatment plants is required, although at the present time primary treatment is considered adequate for the protection of the Mississippi River. As the pollution load increases, increased treatment will be required. Secondary treatment will probably be needed by the year 2000.

DENVER, COLO.

An aggressive State water pollution control program, assisted materially by Federal construction grants, is effecting progressive abatement of stream pollution caused by Colorado municipalities. However, the largest city, Denver, continues to discharge large amounts of inadequately treated sewage into a small stream. The city further has challenged, in the courts, State authority to require a higher degree of waste treatment.

Clear Creek, a small tributary of the South Platte flowing through the northwest environs of Denver, presents a classic example of stream utilization for water supply and waste disposal. In a 15-mile stretch of this small watercourse, 85,000 people are served by 9 sewage plants and numerous small water systems. Clear Creek water is used and reused, and the basin populations are exposed to serious potential health hazards.

The Inter-County Regional Planning Commission is pressing for the abandonment of the present sewerage facilities in Clear Creek Basin and for their replacement by a consolidated metropolitan system. Commission estimates of present and future water needs and sewage volumes in Clear Creek Basin are as follows:

Clear Creek Basin

	1959	1965	1980	2000
Population	85,850	106,500	270,000	380,000
Sewage (million gallons per day)	8.6	10.6	27.0	38.0
Water (million gallons per day)	15.0	18.6	47.3	66.5

While industrial pollution is generally light in the Denver area a contaminated groundwater at the Rocky Mountain Arsenal, an Army Chemical Corps establishment north of the city, points up the potential hazard of industrial waste disposal. In this case, chemical plant wastes were discharged into open unlined ponds for a period of several years. These appear to have caused contamination of a shallow aquifer serving farm wells in the vicinity.

Agriculture and its related industries also cause stream pollution problems in the area. Several large beet sugar mills produce and discharge large volumes of organic wastes into streams during their winter operating season. Return irrigation flows contribute to the deterioration of water quality and the increasing use of chemicals for treatment of crops portends a mounting problem of water pollution, at present unevaluated.

ARKANSAS-RED RIVERS

In the Southwest, the Red River and some of its tributaries contain excessive amounts of mineral pollutants received from both industry and natural sources. The

river is unsuitable for most legitimate water uses such as municipal and industrial water supplies and agricultural purposes. About 50 percent of the mineral pollution is oil brines contributed by industry, amounting to 1,600 tons per day of common salt. Similarly the Arkansas River and some of its tributaries receive large amounts of mineral pollution; however, only about 20 percent is contributed by industry. Average chloride concentrations of 400–700 parts per million are found in both the Arkansas and Red Rivers.

In fiscal year 1958 and fiscal year 1959 the Public Health Service expended $85,000 during each of the 2 fiscal years on a study of the Arkansas River and Red River mineral pollution problems. Purpose of the study is to:

1. Determine on a continuous basis the index of mineral content of these waters.
2. Determine major sources and characteristics of mineral pollution.
3. Develop potential plans for improvement of water quality by elimination or reduction of natural and manmade mineral pollution.

This year (fiscal year 1960) Congress authorized a $400,000 Public Health Service expenditure to accelerate the study. Present plans call for completion of the study and a final report in 1962.

GRAND JUNCTION, COLO.

Pollution of the Colorado River and its principal tributary, the Gunnison River, includes silt and mineral salts in large quantities from natural sources, discharge of untreated or partially treated municipal sewage, discharges and leachings from tailings from uranium processing mills and wastes from an oil refinery.

Rapid growth of industry and concomitant urban expansion will impose problems of planning and construction for municipal water supply. However, as water resources are quite extensive, present and future water supply developments, including irrigation systems, will be able to meet the demands of this period. Water supplies from upland tributary streams, such as Plateau Creek serving the new Collbran Reservoir, are most satisfactory for municipal and industrial uses.

The most serious pollution problem in the area is the discharge of radioactive materials from three uranium processing mills. This pollution presently affects only the Colorado and Gunnison Rivers, and its magnitude is presently not known. Since these waste products may be sources of long-lived radioactive materials, the quality of water in these rivers should be closely checked before the water is used for agricultural, industrial, and municipal purposes. Such an appraisal by the U.S. Public Health Service has been recently requested by the State department of public health.

Future industry and new and expanding communities will need to provide adequate treatment of wastes discharged to water courses to safeguard water quality.

PHOENIX, ARIZ.

Water pollution from industrial sources does not pose any serious problems. Industries established in Phoenix are mainly electronic, and do not produce large amounts of polluting materials. In 1954 one plant was producing a waste product which was treated at the site and disposed of underground. At the present time one industrial plant continues a similar self-treatment process, while a second plant discharges waste to the city sewer system. There is no indication that future industrial development will involve any more serious water polluters.

Ground waters in the Phoenix area are gradually increasing in solids and chloride content. It is felt that some of the pollution of the ground water is being caused by the popular use of "seepage pits" in conjunction with individual sewage disposal systems in the new subdivisions. The soil characteristics in these areas are not conducive to the use of the usual tile field, shallow-soil disposal systems. This has led to the installation of seepage pits, some up to 100 feet in depth. It is the opinion of the local water supply officials that future demands may require the use of desalting equipment for use on brackish ground waters.

SAN JOAQUIN BASIN, CALIF.

The San Joaquin-Tulare Lake Basin is grossly deficient in water resources. This basin contains one-fifth of the area of the State, extending southward from the junction with the Sacramento River and is some 300 miles long. It is the most productive single agricultural area of California. It contains 40 percent of the State's irrigable land.

Irrigation constitutes the largest water use in the basin. Its water resources also provide domestic water supplies for approximately 2.2 million people, of which 80 percent live outside the basin in the San Francisco Bay area. The water exported to the bay area is surface water, while that developed for domestic supplies within the bay area is largely ground water. The surface supplies exported are derived from reservoir developments on the Mokelumne and Tuolumne Rivers near their origins in the Sierra Mountains. Quality of these supplies is very high, permitting consumption with no treatment other than disinfection by chlorination until just recently when treatment for turbidity removal was instituted by the East Bay Municipal Utility District.

Sixty-one domestic and eighty-three industrial sewers in the basin discharge wastes from a population equivalent of nearly 4 million people 20 percent of which is discharged to water courses, the remainder to land. The extensive use of land disposal is quite possibly a contributing factor to the observed deterioration of ground-water supplies. The high waste production of the valley is associated with the food production and processing industry and is seasonal in occurrence, reaching a peak during the late summer and early fall canning season when natural streamflows are quite low.

Severe water quality problems exist in the basin. The extensive development of surface supplies and their use, along with ground water, results in the entire flow of the lower San Joaquin River being composed of irrigation return waters during the summer and fall months. Such waters are poor in quality, containing excessive amounts of minerals leached from soil, as well as fertilizer, insecticides, and herbicides.

In summary, surface water resources of this basin have substantially been completely developed, and inflows from the basin to the delta during recurring annual periods of full streamflow would be of very poor quality, being composed almost entirely of irrigation return and municipal and industrial waste flows.

SAN FRANCISCO BAY

This bay area presents an estuarine problem. The present population contributing wastes to the bay is about 3,029,760. The populations are expected to reach 3,997,000 and 11,833,000 by 1965 and 2015, respectively. Certain areas of the bay are of such shallow depth and of such configuration that secondary treatment of waste is necessary to prevent gross pollution of the receiving waters at the present time. The bay study now being carried on by the Public Health Service for the Corps of Engineers indicates that these areas of the bay will be polluted by 2015 even if wastes receive secondary treatment. The total waste load imposed on the receiving waters will be greater than their assimilative capacity of the waters.

O